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DRAFT Integrated Aquatic Community and Water Quality Monitoring of Mountain Ponds and Lakes in the Klamath Network

Natural Resource Report NPS/KLMN/NRR—2009/xxx

ON THE COVER
One of the Cluster Ponds at Lassen Volcanic National Park, September 2008
Photograph by: Aaron Maxwell

Integrated Aquatic Community and Water Quality Monitoring of Mountain Ponds and Lakes in the Klamath Network

Natural Resources Technical Report NPS/KLMN/NRR—2009/XXX

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1.0 Background and Objectives

1.1 Rationale for Integrated Monitoring of Ponds and Lakes

The NPS recognizes that "aquatic resources are some of the most critical and biologically productive resources in the national park system" and that they "are vulnerable to degradation from activities both within and external to parks" (NPS 2000). The ponds and lakes (hereafter, "lakes" is used to refer to both lakes and ponds) present in Crater Lake National Park (CRLA) and Lassen Volcanic National Park (LAVO) are integral components of the Klamath Network landscape. In general, these ecosystems are complex adapting systems with characteristics that are influenced by local as well as regional environmental conditions (Larson et al. 1994, 1999; Allan and Johnson 1997). Due to their aesthetic value, lakes act as factors that influence or even drive local and landscape-level ecosystem modification by attracting and increasing human activity around and near them (Walsh et al. 2003). Therefore, lakes can be useful indicators of impacts or changes due to various types of environmental perturbation across the landscape, including near-field impacts such as visitor use and far-field impacts such as atmospheric deposition of pollutants and nutrients originating from agricultural activities and climate change (Stow et al. 1998, Vinebrooke and Leavitt 2005).

The Klamath Network vital sign selection process resulted in the identification of two aquatic resource vital signs for monitoring: Aquatic Communities and Water Quality (Sarr et al. 2007). Prioritization of these vital signs was driven by potential natural and anthropogenic stressors on water resources (including physical, chemical, and biological characteristics) of freshwater habitats. Identified stressors of aquatic resources included (1) climate change, (2) atmospheric deposition of pollutants and nutrients, (3) introduced and invasive species, (4) recreational visitor use, and (5) land use, including park maintenance activities. Because aquatic communities and water quality are intrinsically related (see section 1.4), these vital signs have been integrated into a single protocol. In the words of Dr. Robert Wetzel, late Professor of Aquatic Ecology, University of North Carolina, Chapel Hill, "Water quality is biological" (Wetzel 2001).

The use of water quality defined by human needs works well for municipalities concerned about drinking water supplies. However, in this protocol we strive to use "water quality" in terms of the "natural conditions," and not just human needs. This is aligned with the broad purpose of the National Park Service in maintaining natural conditions "unimpaired for future generations."

Initial selection of aquatic communities and water quality did not discern between lentic (standing water – e.g., lakes) versus lotic (running water – e.g., streams) habitats. Fundamental differences in the structure of these two general ecosystem types dictated that a basic division be made in how these habitats are sampled. Protocols on sampling lotic habitats are covered in a separate publication (Dinger et al. in development).

Lakes are integral ecosystems in the overall landscape of many parks. Not only are lakes attractive park visitor destinations, but they also serve as watering holes for park wildlife. Lake ecosystems have been studied over the history of science, both as isolated "mesocosms" (i.e., stand alone self-contained systems) and as integral parts of the landscape, and have provided a rich context for understanding the linkages between stressors and their effects. Consequently, aquatic habitats are known to respond to physical and biological stressors in predictable ways.

For instance, climate change and altered precipitation cycles can alter the amount of available lake habitat and productivity (Gleick 1998). Deposited atmospheric nutrients and resulting eutrophication can cause increased algal blooms, leading to anoxic conditions, fish die-offs, and other water quality problems (Jassby et al. 1994, Wetzel 2001, Sickman et al. 2003). Introduced non-native fish and bullfrogs can radically alter the native food webs, eliminating native, resident species (Adams 1999, Vander Zanden et al. 1999). The strength and predictability of relationships between lake ecosystems and the surrounding environment makes them excellent bellwethers for tracking natural and human-caused environmental changes.

The overall aquatic community of a lake serves as an integrated biomonitoring tool, encompassing short-term and long-term responses to impacts (Rosenberg and Resh 1993). Invertebrates (benthic and planktonic) can rapidly respond to impacts, while fish and amphibians (with longer life cycles) will demonstrate time-integrated responses. Trends in aquatic communities reflect changes in water and habitat quality, so that monitoring aquatic communities and associated habitat characteristics will detect changes in ecological integrity over time. We have chosen to monitor multiple indicators of the lake ecosystem, encompassing key attributes of habitat, chemistry, and biology. The use of multiple indicators for measuring potential ecosystem change will provide us with an integrated and robust system for detecting trends and impacts over time.

Attributes of the lake ecosystems serve as indicators to park landscape impacts as a whole; for example, changes to the hydrologic cycle which will manifest in snowpacks and soil moisture content also will affect the water quality of the lakes. Effects of atmospheric deposition of pollution and nutrients which can infiltrate the terrestrial vegetation, lichen, and soil may be apparent in effects to the trophic status of lakes. In sum, monitoring of lakes serves as a comprehensive approach to address current and future issues for management of park resources.

1.2 Link to National and Regional Strategies

Lake monitoring is being conducted by several other western U.S. National Park Service Inventory and Monitoring networks. These networks include the North Coast and Cascades Network to the north as well as the Sierra Nevada Network to the south. Combined, these Inventory and Monitoring networks will be monitoring mountain lakes from the Canadian border to central California. In developing this protocol, draft protocols from both the Sierra Nevada and North Coast and Cascades Networks have been consulted to ensure that methods and results are as comparable as possible. However, differences in sampling scheme and protocol purpose necessitate differing protocols: the North Coast and Cascades Network has a sampling scheme directed towards a lower number of replicates per park (six) but repeated each year; the Sierra Nevada Network has chosen a sampling scheme emphasizing the measurement of inter-annual trends at four sites and a split panel design to sample a total of 76 lakes every 3 years; the Klamath Network (this protocol) samples a total of 154 lakes over 30 years. The goals of the North Coast and Cascades Network protocol and ours are very similar: to conduct a holistic ecosystem sampling approach that includes water chemistry, fish, aquatic macroinvertebrates, zooplankton, amphibians, and physical habitat. The Sierra Nevada Network is focusing on water chemistry, amphibians, and lake outflow. However, where there is overlap, similar protocols have been utilized throughout. Although an exact overlap is impractical due to differing network logistics and budgets, similar measures that are being conducted at the three networks. Trends in the Sierra Nevada Network and North Coast and Cascades Network will be comparable to observed trends in the Klamath Network, thereby facilitating the development of a regional understanding of condition and trends in high elevation lake and pond ecosystems.

We also have incorporated aspects of several national lake monitoring strategies. The United States Environmental Protection Agency (USEPA) has published three separate manuals on Standard Operating Procedures for lake sampling, all from different programs: (1) Environmental Monitoring and Assessment Program (EMAP) Surface Waters, Field Operations Manual for Lakes (USEPA 1997); (2) Lake and Reservoir Bioassessment and Biocriteria (USEPA 1998); and (3) Survey of the Nation's Lakes – Field Operations Manual (2007). An additional program with the United States Geological Survey (USGS) was investigated (the National Water Quality Assessment Program [USGS 2002]) and although their methods are directed towards wadeable and non-wadeable streams, commonalities were examined and reviewed for inclusion in our protocols (e.g., Quality Assurance Project Plan aspects and water quality sampling procedures). With state agencies, there is no known program within Oregon for lake monitoring and the California Surface Water Ambient Monitoring Program has identified lakes and reservoirs as a high priority for monitoring but allocations of efforts to date have focused on the bioaccumulation of pollutants in the higher trophic levels (e.g., fish).

Further aspects of our protocols have been developed using established techniques in the primary scientific literature. Specifically, we have studied the methodology of principle investigators who have utilized Observed/Expected ratios of biological diversity to develop a quantitative index of lake health (Johnson 2003, Knapp et al. 2005). By incorporating these methods, we are engaging in both regional (Knapp et al. 2005) and international (Johnson 2003) efforts to develop Observed/Expected ratios for lentic communities (see section 2.5.5 for more on derived indices).

1.3 Monitoring History

Lakes in LAVO and CRLA have been inventoried in the past, but overall sampling has not been coordinated or systematic. The exception is long-term monitoring of Crater Lake proper, which has been ongoing since 1983 (Larson et al. 2007). Because the Crater Lake Monitoring Program is base-funded and managed by the park and the lake exceptionally unique, it is not included in the sampling frame of this protocol. Other monitoring of CRLA lentic habitats has been sparse, with a single known survey of the Whitehorse Ponds area that collected limited chemical and biological information (Salinas et al. 1994). A search of EPA Storet did not show any lentic sampling stations within the bounds of CRLA (accessed 21 April 2009, http://www.epa.gov/storet/dbtop.html).

A substantial amount of inventory data has been accumulated for LAVO. The Water Resources Division of the National Park Service has completed the Baseline Water Quality Data Inventory and Analysis report for LAVO (NPS-WRD 1999). The report details results from a total of 218 water quality stations (including streams, lakes, and hot springs) from the park. However, only 25 lakes were found to have existing data. Only three of 218 stations have long-term data, and only one (a stream) has data going back to pre-1985. Additional surveys of LAVO include the Level 1 Baseline Water Quality Report (Currens et al. 2006), which sampled dissolved oxygen, pH, and specific conductivity for 23 lakes. Biological surveys for fish, amphibians, and invertebrates were done by Parker (2008) and Stead et al. (2005). In addition, there has been considerable interest and past research focused on the unusual fumaroles and hot springs of the park (Ingebritsen and Sorey 1985, Siering et al. 2006). In sum, the existing data and knowledge of LAVO waters are either haphazard or sporadic (e.g., NPS-WRD 1999), specialized habitats (e.g., Ingebritsen and Sorey 1985), or recent inventories (e.g., Stead et al. 2005 and Parker 2008).

Existing water quality data will be integrated into Analysis and Synthesis reports, as appropriate, but owing to the general scarcity of data, the prior monitoring was not an influence in development of this protocol.

1.4 Integrated Conceptual Model of Aquatic Communities and Water Quality

The Klamath Network presented graphical conceptual models supporting its overall monitoring design in their vital signs monitoring plan (Sarr et al. 2007). These models support the conceptual approach of integrating the water quality characteristics (i.e., physical, chemical, and biological) and aquatic communities into a single protocol (Figure 1), as well as the focus on integrating ecosystem composition, structure, and function (Figure 2). In this protocol, we integrate aspects of structural, compositional, and functional measures of the ecosystem. For example, we will monitor the ecosystem structure of lakes (e.g., shoreline habitat and lake morphometry) and aquatic communities (fish, amphibians, zooplankton, and macroinvertebrates). Combined with multiple water chemistry parameters (e.g., pH, alkalinity, and nutrients), we will be able to address functional aspects of the trophic structure of these ecosystems.

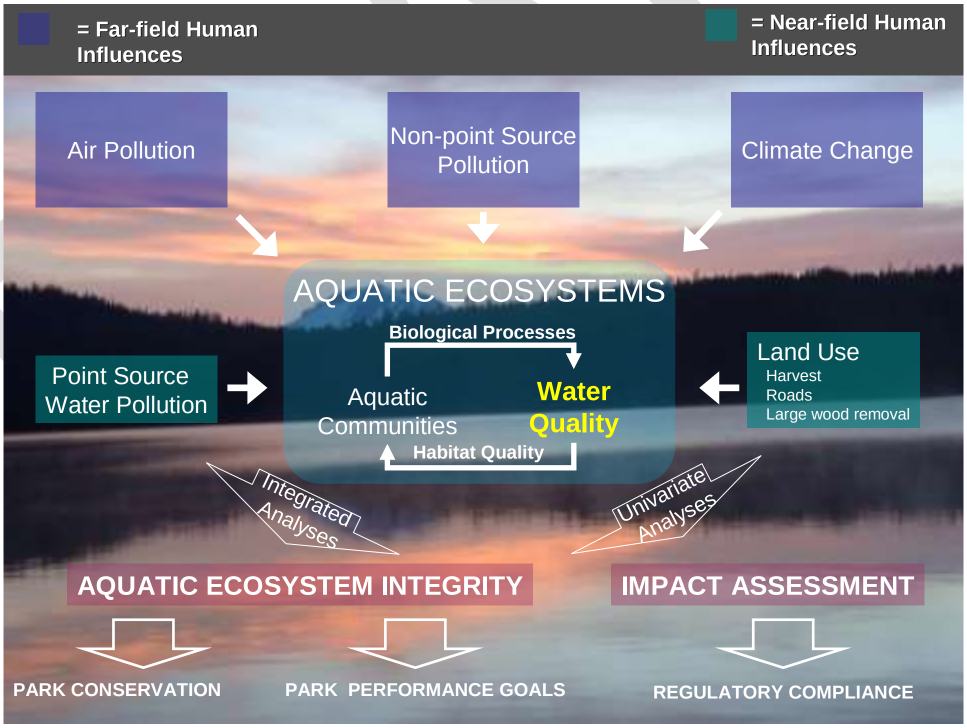

Figure 1. Conceptual ecological model showing the integral relationships between water quality and aquatic communities in aquatic ecosystems.

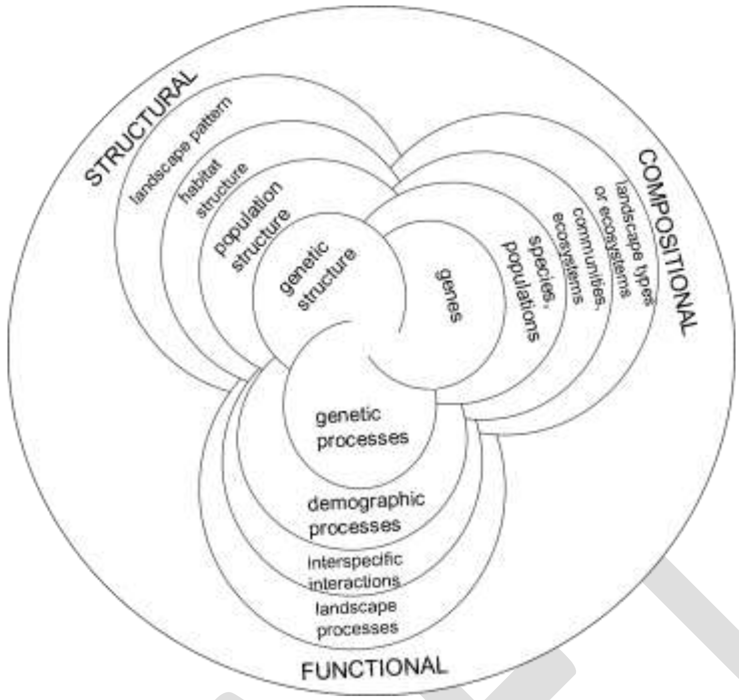

Figure 2. Conceptual model of the multiscale hierarchy of biodiversity indicators that describe composition, structure, and function at each level of organization (from Noss 1990).

By sampling multiple components of our ecosystem models, we utilize a diversified, multispecies approach that is the most comprehensive and robust way to ensure that important trends are detected, as argued by Manley et al. (2004). Monitoring multiple species and attributes together will track changes in ecosystem composition, function, and structure better than single species approaches or schemes focusing on a single aspect (e.g., water chemistry).

1.5 Existing and Potential Ecosystem Stressors

As mentioned above, five basic stressors, identified as part of the vital signs scoping process, that could impact the water quality and aquatic communities of Klamath Network lakes include: (1) climate change; (2) atmospheric deposition of pollutants and nutrients; (3) presence or introduction of non-native and invasive biota; (4) non-recreational land use practices within and external to parks; and (5) visitor recreational activities within parks. These stressors were considered in the selection of parameters to monitor.

1.5.1 Climate Change

Concerns about the potential impacts of climate change are well documented (IPCC 2007). Researchers have documented that various physical, chemical, and biological characteristics of lakes (e.g., water-level and temperature, nutrient concentration, pH, dissolved oxygen, productivity, and composition of the macroinvertebrate community) can be good indicators of impacts due to climate change (McKnight et al. 1996, Arnott et al. 2003, and O'Reilly et al. 2003). Even modest temperature increases in the western United States may cause significant changes to the hydrologic cycle, as manifested in earlier snowmelt, earlier ice-out on lakes, reduced summer base flows (Dettinger et al. 2004), a lower snowpack volume at lower to mid elevations (Knowles and Cayan 2001), and increased flooding due to rain-on-snow events (Heard et al. 2009).

1.5.2 Atmospheric Deposition
Atmospheric contaminants have been recognized as a potential stressor of ecosystems, both aquatic and terrestrial, for several decades (Schindler 1987, Landers et al. 2008). A classic example is acid rain, where SO_x and NO_x precursors from combustion were transported thousands of kilometers from their source and deposited by precipitation, causing sensitive ecosystems to acidify (Likens et al. 1979). Similar concerns with nutrients (e.g., from agricultural fertilizers) and pollutants (e.g., volatile organic chemicals, toxicants, etc.) can also perturb ecosystems by eutrophication processes or toxicity effects (Landers et al. 2008).

1.5.3 Non-native and Introduced Species
Introduced, non-native, and exotic species can cause large changes to native biodiversity and the trophic dynamics of lakes (Vander Zanden et al. 1999, Knapp et al. 2001, Parker et al. 2001, Schindler and Parker 2002, Boersma et al. 2006). In parks of the Klamath Network, the introduction of kokanee (land-locked sockeye salmon [*Onchorhynchus nerka*] and Rainbow trout [*Onchorhynchus mykiss*]) in CRLA, and Brook trout (*Salvelinus fontinalis*) in LAVO are potential ecosystem stressors. Emerging, potential invasives also include both vertebrate (e.g., American bullfrogs [*Rana catesbeiana*]) and invertebrate (e.g., New Zealand mudsnails [*Potamopyrgus antipodarum*]) taxa. Considerable threats also exist from emerging diseases, such as chytrid fungus (*Batrachochytrium dendrobatidis*), which affects native amphibians and whirling disease (*Myxobolus cerebralis*) that impacts native salmonids.

1.5.4 Non-recreational Land Use Practices within and External to Parks
Land use practices that include potential stressors relevant to Klamath Network parks include: park operations (e.g., construction and road maintenance), past mining operations, dam operations, sewage and wastewater, fire management, timber harvest, geothermal explorations, and trespassing livestock grazing (Hoffman and Sarr 2007). Additional concerns stem from development and the cultivation of illegal crops (especially marijuana) within park boundaries. The potential pathways whereby these stressors manifest themselves in aquatic ecosystems is beyond the scope of this narrative, but increased sediments, pollutants, and hydrologic changes from both direct and indirect impacts are possible.

1.5.5 Visitor Recreational Activities
Potentially damaging recreational uses include camping, packstock use, boating, and fishing. Recreational impacts may include mechanisms from the above stressor categories. For example, camping can cause the input of nutrients from improper disposal of camper waste, or anglers and the use of boats can contribute to the introduction and dispersal of non-native species.

1.6 Vital Sign Objectives
The monitoring and sampling objectives for this protocol were largely determined at scoping meetings with network ecologists, USGS specialists, and park resource experts. Refinement based on feasibility, logistics, and budgetary realities determined during the pilot project (Appendix A) was done by the primary author.

From this development period, we have developed broad monitoring questions:

- What are the status and trends of ecological condition in mountain lakes in the Klamath Network?
- How are climatic trends associated with water quality and aquatic communities?
- How is water quality changing with respect to water quality standards?
- What is the distribution and relative abundance of non-native species in lake ecosystems? How are invaded habitats different from non-invaded habitats? How do aquatic communities differ between invaded and non-invaded systems?
- What is the status and trends of amphibian populations? Are the amphibians affected by wildlife disease?
- What proportion of lakes does not meet water quality criteria? What proportion show ecological impairment?

1.6.1 Monitoring Objectives

Based on the broad monitoring questions we identified, the primary goal of this protocol is to *determine the status and trends of ecological condition in mountain lakes of the Klamath Network*. By taking an integrated approach of monitoring multiple aspects of the ecosystem, this protocol will also inform and address the other monitoring questions. Many of the aspects monitored will be focused on providing an early-warning system (integral to the vital sign concept). However, associations of ecological condition and stressors will be based on a correlative approach *that cannot by itself determine cause and effect relationships*. Investigation of cause and effect relationships will require formal experimental research, which is beyond the scope if this monitoring effort. Rather, it is our aim to provide design-based inferences of significant impairment trends to alert managers to the research needs to identify and address the root causes of such impairment.

To address the primary goal, we have delineated specific objectives:

Objective 1: Characterize the environmental and aquatic communities in a probabilistic sample of mountain lakes and determine status and trends in key univariate and multivariate variables.

This objective entails the majority of the field work of this protocol; a wide selection of parameters will be used for the habitat and water quality and the biotic communities will include sampling for fish, amphibians, zooplankton, and macroinvertebrates. This survey work will meet several of the broad monitoring questions listed above, such as the status and trends of amphibian diseases and detection of exotic organisms.

Focal univariate measures are park averages (for park-based assessment): biodiversity (using species richness and Shannon Index), dissolved organic carbon, temperatures, alkalinity, substrate composition, and nutrients. Some measures will be used as correlative and explanatory variables (e.g., lake area, lake depth, chemistry) while other measures will be used for status and trend analyses (e.g., species richness).

Focal multivariate measures include: Index of Multivariate Seriation of fish, zooplankton, invertebrates, and physiochemical factors (Clarke 1993), as well as univariate indices based derived from multivariate data (e.g., Hilsenhoff Biotic Index, a weighted tolerance value for invertebrates).

Objective 2: Develop indices (e.g., Index of Biotic Integrity) and predictive models (e.g., RIVPACS [River Invertebrate Prediction and Classification System] Observed/Expected models) of ecological condition that integrate different aspects of the biological community to give robust estimates of ecological condition.

This is a long-term objective that can only be achieved once a large sample size of lakes has been characterized. Upon development, both RIVPACS observed/expected models and Index of Biotic Integrity will be used to address the monitoring question of ecological impairment. These models will be integrated over the entire aquatic community (i.e., fish, amphibians, zooplankton, and macroinvertebrates) rather than based solely on invertebrates. RIVPACS have the advantage of being easily interpreted information about the biodiversity of the site, whereas an Index of Biotic Integrity can incorporate information about the structure and functioning of the ecosystem.

Objective 3: Use sampled parameters to determine trophic condition of lakes using Carlson's Trophic State Index.

This objective links several parameters (secchi depth, nutrient chemistry, and algal concentrations) to the trophic status of the lake, enabling the evaluation of status and trends in eutrophication. Tracking the Trophic State Index (Carlson and Simpson 1996) provides an estimate of the influence that stressors have in eutrophication.

Objective 4: Determine how measures vary as a whole or independently to understand how various aspects of lentic communities are related.

This objective will help improve understanding of the nature of change in these communities and should provide a weight-of-evidence approach to assessing environmental change associated with stressors. This objective will be met by exploratory data analysis methods, such as simple correlations, to more advanced correlations of distance matrices (and even second stage ordinations) for community data.

1.6.2 Water Resources Division Program Objectives

The National Park Service Water Resource Division provides funding for and details about additional objectives for water quality monitoring. Specific objectives linked to the National Park Service Vital Signs program are detailed in Part A: Identification of Priority Impaired and Pristine Waters for the Water Quality Vital Signs Monitoring Component, available at: http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/wqPartA.pdf

Objective 1: Assist parks with "impaired quality waters," also known as "303d" lists as defined by the Clean Water Act. The method of assisting should be in two functions:

> a. Gather information on the pollutants that exceed standards that will assist the park and the state to design specific pollution prevention or remediation programs through Total Maximum Daily Loads.

b. Determine whether the overall program goal of improved water quality is being achieved after the implementation of effective pollution control actions.

Currently, there are *no 303d sites within the habitats and parks covered by this protocol*, and hence this specific objective is not pertinent. However, the primary objectives of this protocol will meet the goal of assisting in identifying potential or developing 303d sites. This protocol also recognizes that future conditions (e.g., park expansion, new stressors, etc.) may result in 303d waters being covered by this protocol. We will work with the individual park to determine the best method to monitor emerging 303d waters. Every 3 years, when an Analysis and Synthesis report is conducted, state 303d lists will be reviewed.

Objective 2: Assist parks with monitoring of "Outstanding National Resource Waters" or Tier 3 waters as defined by the Clean Water Act. The method of assisting should be in two functions:

a. Allow characterization of existing water quality and to identify changes or trends in water quality over time.

b. Identification of specific existing or emerging water quality problems

Currently there are no specific Outstanding National Resource Waters in any of the parks of the Klamath Network. This specific objective and functions dictated by the Water Resources Division are met by monitoring the lakes and streams of the Network parks.

1.6.3 Measurable Objectives

Measurable objectives to meet the monitoring goals and objectives of this protocol (see relevant SOPs for details) include:

- Establish probabilistic sampling locations within LAVO of safe and accessible lakes. In CRLA, establish sampling at all perennial lakes, excepting Crater Lake.
- Measure habitat parameters at each sample location: percent substrate type, area, depth, elevation, number of inlet and outlets, terrestrial vegetation type, and photographic records.
- Collect core water quality parameters in a vertical profile at the deepest portion of the lake: dissolved oxygen, temperature, specific conductivity, turbidity, pH, oxidation/reduction potential, and qualitative water level.
- Collect water samples from the deepest portion of the lake to measure anions, cations, alkalinity, nutrients, dissolved organic carbon, and Chlorophyll *a*.
- Collect semi-quantitative samples of littoral zone macroinvertebrates.
- Collect zooplankton tows of water column.
- Conduct Visual Encounter Surveys for amphibians to develop species list and approximate numbers.
- Utilize gill nets to determine presence and catch per unit effort of fish populations.
- Develop and maintain a database and associated metadata derived from the sampling procedures.
- Report status every 3 years for key parameters in summary reports.

- Write Analysis and Synthesis reports every 6 years that explore relevant topics in depth. Specifically, individual Analysis and Synthesis reports will detail trends in core parameters and species composition and abundances, explore data patterns to relate stressors to observed trends, develop observed/expected models for species assemblages, and develop indices of biotic and ecological integrity.

2.0 Sampling Design

The two parks that are the focus of this protocol, LAVO and CRLA, are the only parks in the Network with mountain lakes. LAVO has at least 239 known lakes, whereas CRLA only has 38 potential lakes, with many known to be ephemerally-flooded wetlands (about 83% are not perennial, see below). Hence, we will implement a probabilistic rotating split-panel design for LAVO but will be conducting a complete census of perennial lakes in CRLA. The sample size varies for the parks covered by this protocol (Table 1). At LAVO, each sampling season will include 15 “index” (always revisited) sites and 15 “survey” sites (revisited every 30 years), plus a single “judgment” site (always revisited) for a total yearly sample size of 31. Sample size for CRLA is expected to be between six and ten. A single “judgment” site at Redwood National and State Parks is also done. Details on this sampling scheme are below. Details about how, why, and the purpose of judgement sites are detailed below (section 2.1.1).

Table 1. Sample sizes for each park unit and panel type. [1] = panel of revisited sites, [2] = panel of 30 year revisits, [3] = panel of selectively chosen sites, always revisited. See text for more details on panel type.

	Panel type			
Park Unit	Index[1]	Survey[2]	Judgment[3]	Total
Lassen Volcanic National Park	15	15	1	31
Crater Lake National Park	6-10			6-10
Redwood National and State Parks			1	1
All units				38-42

2.1 Rationale for Selection of Sampling Design

The Klamath Network has chosen a split-panel, revisit sampling design to monitor water quality and aquatic communities in LAVO (Urquhart et al. 1998, McDonald 2003). This design mirrors other monitored vital signs for the Network (e.g., vegetation monitoring and stream monitoring). This sampling design consists of “panels” that denote sites of differing revisit intervals. In our design, we have two panel types: a panel of “index” sites that that are always revisited and panels of “survey” sites that are revisited every 30 years (Table 2). The advantages and disadvantages of this sampling scheme are discussed in detail in the Klamath Network’s Vital Sign Monitoring Plan (Sarr et al. 2007), but details of each panel type bear repeating here.

The Klamath Network has worked closely with statisticians and water quality professionals from Colorado State University, University of Idaho, Montana State University, and the National Park Service Water Resource Division to ensure a sampling scheme that provides the greatest power to *determine status and detect trends*. In overly simplified terms, sampling the same sites every period (i.e., only index sites) will maximize power to determine trends, whereas sampling a complete new set of sites with no revisits (i.e., only survey sites) will maximize estimates about status (Urquhart et al. 1998, Urquhart and Kincaid 1999). Index sites allow for the incorporation of a variance term based on site, so that the effect of temporal variation (trends) can be analyzed separately from site variation. Survey sites do not have a temporal variation component; rather, they represent the spatial variation of the park, thereby making the estimate of status applicable to the entire park landscape.

Table 2. Schematic of split-panel design implemented by the Klamath Network for lake monitoring of Lassen Volcanic National Park. Years after 2040 repeat the pattern.

Panel type (n=15 for each)	Sampling Year										
	2010	2013	2016	2019	2022	2025	2028	2031	2034	2037	2040
Index Sites	X	X	X	X	X	X	X	X	X	X	X
Survey 1	X										X
Survey 2		X									
Survey 3			X								
Survey 4				X							
Survey 5					X						
Survey 6						X					
Survey 7							X				
Survey 8								X			
Survey 9									X		
Survey 10										X	

A balanced design of revisit sites with a separate set of sites that are essentially a new sample of sites can thus provide insight to trends, as well as increase the spatial extent of new sites for status estimates. Another way of describing this is that Index sites are focused on describing temporal variation and trends in ecological condition, whereas Survey sites are focused on describing spatial variation and status in ecological condition. The sampling scheme is designed to provide the most robust method for meeting both of these protocol objectives, given overall logistical and budgetary constraints.

2.1.1 Judgment Sites

In addition to Index and Survey panels, a third panel will be monitored under these protocols. This panel, as defined in Sarr et al. (2007), is termed “Judgment,” which is composed of sites that are subjectively selected because either: (1) they have a history of sampling, (2) they are accessible, or (3) the target population is very specialized or unique. Another justification is that certain sites may be facing specific threats and monitoring for these threats is best concentrated at such sites. The continuation of existing monitoring or focused monitoring for special populations or threats is valuable in its own right, but because such sites are usually not probabilistic, they can only be used to make inferences to the specific sites in question. Recognizing these caveats, judgment sites were minimized; sites were selected with input from individual park specialists at protocol scoping meetings.

- Lake Helen Judgment Site (LAVO) - this site was selected as a monitoring priority from park resource personnel because it: (1) is a high use site; (2) receives year-round use; (3) has very little surrounding vegetation and a major park roadway next to it; (4) has high levels of illegal boating activity, increasing risk of invasive species; and (5) has a low buffering capacity against acid deposition. In relation to other lakes of LAVO, this buffering capacity is especially low (average August 2005 alkalinity measurement = 3.6 mg/l, park average = 21.3 mg/l measured as mg/l $CaCO_3$ (Currens et al. 2006).

- Freshwater Lagoon Judgment Site (Redwood National and State Parks) - this site was selected owing to several unique features: (1) it is no longer a proper functioning lagoon, having been cut off from the Pacific Ocean by US Highway 101; (2) it saddles the park boundary, with half on state lands, and half on NPS land; (3) the state portion has been extensively and currently stocked with exotic fish (e.g., smallmouth bass, *Micropterus salmoides*; Japanese pond smelt, *Hypomesus olidus*; and brown bullhead, *Ictalurus nebulosus*) as well as being invaded by exotic vegetation (Brazilian waterweed, *Egeria densa*) and exotic invertebrates (apple snail, probably *Pomacea* sp.). It is also a likely place for emerging new aquatic invasive organism and hence early detection here may warn park staff of new threats to the rest of the park.

2.2 Target Population

Mountain lakes in the Klamath Network occur exclusively in LAVO and CRLA. Additional lentic habitats within the Klamath Network include several coastal freshwater lagoons and artificial ponds in Redwood National and State Parks and a large reservoir (Whiskeytown Lake) located in Whiskeytown National Recreation Area.

Outside of the judgment sites, the target population for this protocol is all mountain lakes that are:

- Perennial – This selection criterion is applied to remove habitats that are influenced by seasonal desiccation which could mask other stressors of interest. It also ensures that data collection can always occur at the sites, assisting in data completion goals (SOP #16: Quality Assurance Project Plan).
- <25 m maximum depth – This selection criterion removes large lakes that are characterized by different physical and environmental processes. While monitoring these lakes is valuable, they would require separate methodology to adequately assess and they are a numerical minority of sites within the Klamath Network.
- <1000 m from a travelable road or trail – This selection criterion reduces logistical constraints to field crews, such as travel time, to ensure that each site can be sampled in the allotted time frame for achieving sampling objectives.
- In topographies with slope <30 degrees – This selection criterion ensures crew safety and that access to lakes is doable.

2.3 Sample Site Selection/Membership Design

2.3.1 Lassen Volcanic National Park

Sites in LAVO are chosen using a Generalized Random Tessellation Stratified design (GRTS – pronounced “grits”) (Stevens and Olsen 1999, 2004). This design employs a systematic sampling technique to obtain a spatially balanced probabilistic sample. A particularly attractive feature of GRTS is the ability to accommodate unequal probability sampling by allowing the probability of individual sampling units to vary. In the case of the lake and pond selection, sites that do not fit the criteria in section 2.2 are assigned a probability of zero. This procedure also produces a spatially balanced over-sample (i.e., a list of additional sites to sample if sample points need to be replaced or added). Since the GRTS method creates spatially balanced and dispersed sample sites, it minimizes spatial autocorrelation among sites and maximizes the effective sample size for a given number of sample sites, which should help increase statistical power.

We have focused on a spatially balanced design because a simple random sample, although the most conceptually easy and statistically simple design to implement, can produce a cluster distribution of sites. The GRTS output is a list of sites, that when visited in order, produces a spatially balanced selection across the landscape. Hence, a single list of all possible sites will be used to populate all the frames. The first 15 sites are used for index sites, the next 15 are used for survey panel #1, the next 15 are used for survey panel #2, and so on, to panel #10. In the event that a site cannot be sampled (e.g., the pond was dry or inaccessible), the next site on the list is substituted for that panel. This assures that the index panel, as well as each individual survey panel, is spatially dispersed.

Although the GRTS procedure is spatially balanced and is not a "simple random sample," aspects of the panel design will be treated as a random sample for analytical purposes. In other words, the assumption that the index sites are a random selection of sites for the purpose of extrapolating status and trends to the entire population is valid. Details on methodologies for analyzing split-panel design are covered in section 4.4: Data Analysis and Reporting.

The National Hydrography Dataset (NHD), containing geospatial hydrologic data that enumerate all lentic habitats within the park, was used to populate the Geographical Information System (GIS) database for running the GRTS draw with a custom script in the statistical software program *R*. Prior to running the draw, potential site locations not fitting the criteria described in section 2.2 were removed, as were prior selected judgment sites. The *R* script "spsurvey" was used to draw the site list from remaining locations in each park (Kincaid 2006). Table 3 provides a summary of the numbers and proportions of lakes available for inclusion, excluded by the criteria, and total number sampled through the program.

Step by step site selection procedures using GRTS are further outlined in SOP #3: Site Selection, as are the results of the GRTS draw. However, the process of using the computer program *R* is beyond the scope of this protocol. Note however, that SOP #3: Site Selection should only have to be used at the initiation of the protocol prior to the first field season and will not need to be done prior to every field season. It is provided to give the field crews and incoming Project Leads the proper context for the survey design and rationale. It is also possible that a new GRTS draw may be necessary if the sampling population changes over time (as in Irwin 2004).

Table 3. Lakes ("Sites") within Lassen Volcanic National Park showing results of criteria filters and total lakes sampled through protocol implementation. NHD = National Hydrography Dataset.

	# of sites	% of total sites
Sites in NHD GIS file	239	100%
Sites excluded by selection criteria	36	15%
Sites available for GRTS draw	203	85%
Sites sampled through 30 year cycle of protocol	165	69%
Sites not sampled in protocol:	74	31%

Example photos of lakes included in the sampling frame are presented in Figure 3. These sites encompass a wide variety of environments, from meadow ponds to high elevation alpine lakes. The figure is presented to give the reader an overview of the lakes/ponds and is not intended to be an exhaustive presentation of sites.

Figure 3. Lake and pond habitats of Lassen Volcanic National Park. Clockwise, from upper left: Cluster Pond #4, Cluster Lake #4, Lake Helen, Unnamed Lake, Cliff Lake, and Cluster Lake #3. Photos by Aaron Maxwell.

2.3.2 Crater Lake National Park

Initial scoping of available sites in CRLA included examination of the National Wetlands Inventory dataset for this park unit, which detailed 139 sites, including both emergent palustrine (marsh and swamp wetlands) and lacustrine (lake/pond) sites. However, the dataset only identified sites within the rim of Crater Lake caldera as being lacustrine (i.e., are a part of Crater Lake proper). A separate dataset provided by park specialists only identified 38 potential lakes, not including wetlands.

A preliminary site visit to 23 of these potential sites on 28-30 October 2008 revealed that only four of these sites were potentially perennial (see Figure 4 for examples of habitats encountered). Assuming the ratio of 17% (4 of the 23 visited) being perennial, the total number of perennial sites will be six or seven (17% of 38 potential sites). For planning and budgetary purposes, we have assumed that a minimum of six to a maximum of ten sites will be perennial.

Sites determined to be ephemeral in the preliminary site visit will be excluded from the list of sites to be visited. Sampling will start with the four sites known to have water during the 2008 site visits, and then sampling will commence at the rest of the unknown sites (i.e., those not visited during the site visits of October 2008). As these sites are shown to be ephemeral, they will be removed from the sampling list. If future follow-up sites are shown to be ephemeral, they will be removed from the sampling list, even if prior year(s) sampling had occurred.

Figure 4. Examples of Crater Lake National Park lakes, including probable ephemeral sites. All sites are unnamed locations. Only the lower left is likely a permanent water body. Photos by Aaron Maxwell.

2.4 Frequency and Timing of Sampling

2.4.1 Sample Frequency

Sampling of lakes will occur every 3 years as a part of the overall design of integrated aquatic communities and water quality (Table 4). In between these sampling periods, wadeable streams (covered in a separate protocol) will be implemented.

Table 4. Rotational pattern of sampling frequency of integrated water quality and aquatic communities for both lakes and wadeable streams. After 2015, the pattern continues.

Habitat type	Park units	2010	2011	2012	2013	2014	2015
Lakes	Lassen Volcanic National Park	X			X		
	Crater Lake National Park	X			X		
	Redwood National and State Parks	X			X		
Wadeable Streams	Whiskeytown National Recreation Area		X			X	
	Lassen Volcanic National Park		X			X	
	Oregon Caves National Monument		X			X	
Wadeable Streams	Redwood National and State Parks			X			X
	Crater Lake National Park			X			X
	Oregon Caves National Monument			X			X

2.4.2 Sample Timing

Timing of sampling efforts at individual sites across years will be kept as constant as logistically possible. This will help to reduce inter-annual variation that may be due to phenological characteristics of the lakes being sampled. For example, if Lake Helen is sampled on 15^{th} July 2010, we will attempt to repeat the visit between 14^{th}-16^{th} July 2013. Sampling Lake Helen later in the field season, such as in late August or early September will introduce variation from such things as insect emergence, zooplankton cycles, lake turnover, etc. After the first field season, dates for all index sites visits will be recorded and used for planning the next sampling period in perpetuity.

An additional concern is the timing of sampling relative to the panel type of each site. For instance, all index sites should not be collected in the early part of the season, and all the survey sites collected in the late season. This will introduce variation between the two panel types that may hinder the integration of the two panel types into single analyses. Hence, the sampling order of index and survey sites will alternate, so within a 4 day sampling week, two index and two survey lakes will be sampled.

Another aspect of sample timing that can affect results is diurnal shifts in parameters. For instance, primary production may peak during times of higher solar radiation (middle of the day), so that dissolved oxygen correspondingly increases as these times. Measurements of dissolved oxygen taken at mid-day may thus differ than values taken at dawn. Another variable aspect can be the behavioral differences in amphibians from mid-day to dusk activities that can affect detectability during surveys. To reduce variability in these parameters, field crews will perform all sampling during standard daylight hours; generally between 10AM and 3PM. Obviously logistics of site access will dictate actual start times, but crews cannot start sampling pre-dawn.

Additionally, time of sampling will be recorded for measured parameters to help in the interpretation of variation relative to time of sampling.

Seasonal sampling will commence in LAVO, with the anticipation that snowmelt will occur at this park before snowmelt occurs in CRLA. Because there is the possibility that the first sampling period may be an unusually early snowmelt, several weeks will be added to the actual start period. The logic for this is that the initiation of the protocol based on an unusual dry year may result in an inability to access lakes at the scheduled times in years characterized by a heavier snowpack. After completion of sampling the index, survey, and judgment sites in LAVO, crews will initiate sampling of sites in CRLA. The Freshwater Lagoon in Redwood National and State Parks will be the final site sampled of the year. The rationale for finishing in the Freshwater Lagoon is that the numerous exotic organisms of this habitat would pose a threat to the other parks of the Network, and by finishing there, the risk of transmission of these non-native species will be minimized. Also, the biological activity at this coastal site is unlikely to decrease materially by September, due to its much milder climate. The general schedule of field work is shown in Figure 5.

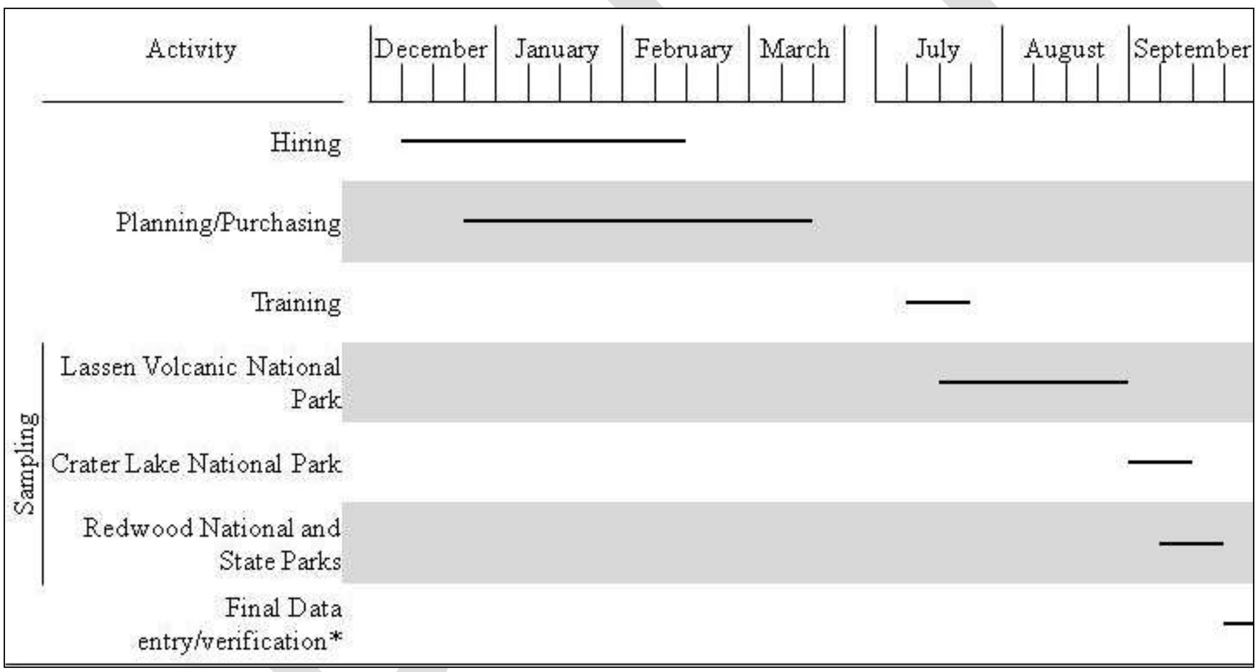

Figure 5. Timeline for protocol hiring, planning, training, and sampling. *Final data entry is for any remaining sites to be entered into the database, and final verification of data by the Project Lead. Actual data entry during the sampling season is done concurrent to sampling.

2.5 Rationale for Selection of Parameters

Each parameter to be measured was chosen for the following reasons:

- It directly or indirectly addresses protocol objectives.
- It is mandated by National Park Service Water Resources Division.
- It can be used to develop or derive an index or indices that address protocol objectives.
- It places other parameters in a context to better address protocol objectives.

- It assists in making correlative statements between response variables and stressors.
- It is a cost-effective alternative to other parameters.

In this context, parameters are defined as features allowing quantitative or semiquantitative measurements (e.g., numerical, ordinal, or categorical data) through field visits or laboratory analyses. Table 5 provides a summary overview of parameters to be monitored; the text below explores the context and rationale for each parameter in more detail.

2.5.1 Core Parameters

The core parameters represent a set of water quality attributes that will be measured as part of all NPS Water Resource Division funded water quality monitoring protocols. As such, these attributes contribute some measure of consistency and comparability of water quality conditions among multiple monitoring programs (NPS 2002). With the exception of water level, all core parameters will be measured in a profile at the deepest part of the lake (determined using a hand-held sonar unit). However, the use of the word “core” does not imply that these parameters are more or less important that other parameters.

Water temperature is a critical variable controlling many ecosystem processes, both physical and biological, and it can impact almost all functions within an ecosystem. For instance, temperature controls aquatic biota metabolisms and affects the breakdown of organic matter, nutrient uptake, and primary production (Allan and Castillo 2007). Temperature also affects dissolved oxygen, with denser colder water being able to sustain higher amounts of dissolved oxygen. It also affects physical processes, such as lake stratification, which has important implications for nutrient availability and the “growing zone” of a lake (Cole 1994). Lake water temperature is also a critical parameter for tracking climate change’s manifestation in these important park ecosystems.

Water pH, the measure of hydrogen ion concentration in the water column, is a critical attribute of any water body with many physical and biological effects. Low pH (<7) indicates acidic waters, and high pH (>7) indicates basic water. Most aquatic plant and animal species occur within specific habitat envelopes of pH conditions and changes in pH will likely result in changes in species relative abundance or overall species composition. In addition, the pH of the water will determine the solubility of many heavy metals, which can have negative impacts on invertebrate biodiversity (Wiederholm 1984, Allan and Castillo 2007). Acidification of water also has deleterious effects on zooplankton communities (Locke 1990).

Specific conductance, or simply *conductance*, the ability of a water body to conduct an electric current, is directly correlated with the dissolved ion concentration in a body of water. In essence, the “purer” the water, the lower the concentrations of dissolved salts and thus the lower the conductance. Changes in conductance will detect changes in major ions or nutrients, such as overall potassium, calcium, and other anions and cations.

Dissolved oxygen, a critical element for the aquatic biota of a lake, is closely linked to physical and biological processes. For instance, respiration, photosynthesis, and atmospheric exchange are the principle processes that affect or are affected by dissolved oxygen concentrations. In addition

Table 5. Parameters to be measured under this protocol. [1]= See SOPs for more details; "where" indicates actual location *within* site that parameter will be taken. [2]= actually "biological," but collected with water chemistry sample.

Parameter	SOP#	Where[1]	Methodology[1]
Water chemistry - field			
Dissolved oxygen	10	Deepest portion of lake	Multiprobe water quality sonde profile
Oxidation/reduction potential			
pH			
Specific conductivity			
Temperature			
Turbidity			
Acid Neutralizing Capability	9	0.5 m below surface, 0.5 m above lake bottom at deepest portion	Field titration kit
Water chemistry - Lab			
Anions (Cl, SO_4)	8,9	0.5 m below surface, 0.5 m above lake bottom at deepest portion	Ion chromatography
Cations (Na, Ca, K, Mg)			Spectrophotometry
Dissolved organic carbon			Combustion-Infrared
Dissolved total nitrogen			Persulfate Digestion
Dissolved total phosphorous			Spectrophotometry, Persulfate, sulfuric acid digestion
NO_3-N + NO_2-N			Cadmium reduction
Chlorophyll *a*[2]			Fluorometer
Lake Environment			
Percent Substrate type	11	Wetted perimeter	Shoreline walk-around, entry into GPS unit, extraction of data using GIS
Area			
Maximum length			
Maximum width			
Shoreline length			
Relative water level			
Water clarity	8	Deepest portion of lake	Secchi disk
Maximum depth			Hand-held sonar
Aquatic Community			
Zooplankton	8	Deepest portion of lake	Zooplankton tows
Benthic macroinvertebrates	11	Littoral zone	Semi-quantitative sweep net
Amphibians	11	Littoral zone/water-terrestrial interface	Visual encounter survey
Fish	7	Open pelagic zone	2 hr gill net

to warm water temperatures, high microbial activity, driven by organic pollution, can drive up the demand for dissolved oxygen resulting in anoxic conditions.

Water level is an additional parameter to be measured dictated by the Water Resources Division. Water level is indicative of annual changes in the water cycle, the amount of winter precipitation an area may have received, and likely to be impacted by climate change. In the Klamath Network, estimates of lake water level will be based on elevation readings of the wetted perimeter, and qualitative estimates by the field crew.

2.5.2 Water Chemistry Parameters

These parameters include field and laboratory measurements. In general, water chemistry parameters are indicative of the ecosystem quality that the aquatic communities live in and hence can have a profound effect on these organisms. By themselves, they can equate to the generalized notion of "water quality," indicative of water pollution not meeting water quality standards or indicate a stressor and effect (for example, high nutrient load leading to eutrophication). Analysis of the chemical characteristics of water is fundamental to the effective monitoring of the water quality of aquatic resources. Water chemistry parameters are indicators of the productivity or "trophic" state (e.g., oligotrophic, mesotrophic, or eutrophic) of aquatic ecosystems, the natural variability of conditions within and among trophic states, the capacity of ecosystems to support biotic communities, and potential changes in ecosystem status and trends.

Acid Neutralizing Capacity (ANC), similar to Alkalinity, is the resistance of the water body to acidification. It is measured in the field using unfiltered water (note: when done on filtered water, it is termed Alkalinity; when on unfiltered water it is ANC). Here, we perform the tests on unfiltered water to obtain the actual ANC value for a site, but it is measured using an "alkalinity" test kit. As a measure of the buffering capacity of a lake, it is indicative of the lake resistance to declines in pH, either through natural processes or anthropogenic stressors.

Anions/Cations being monitored include the two predominant anions (negatively charged ions – SO_4^{2-} and Cl^-) and four cations (positively charged ions – Ca^{2+}, Na^+, K^+, and Mg^{2+}). These six ions, along with carbonates (estimated with the ANC measurement), make up most of the ions in lake water. These ions are important indicators of the edaphic context of the lake or pond, with different ion concentrations reflecting variation in watershed geology, vegetation, and weathering processes. However, SO_4^{2-} is also common as an indicator of pollution (e.g., from mining waste or fertilizers). It is important to note that SO_4^{2-} is common in volcanic regions such as CRLA and LAVO.

Dissolved organic carbon is a measure of detritus in the water column. Sources of dissolved organic carbon (DOC) can be from autochthonous (within the lake) processes through extracellular release by algae or senescing organisms or bacterial degradation or allochthonous (terrestrial) processes (e.g., leaf litter breakdown carried into the lake by wind or water). Utilization and uptake of DOC by bacteria and phytoplankton is enhanced by higher temperatures and light; hence decreasing trends in DOC may indicate climate change, although acidification is also a potential cause in decreasing DOC (Schindler et al. 1992, Wetzel 2001).

Nutrients include the dominant forms of nitrogen and phosphorous. Both elements may be limiting nutrients to lake ecosystems, controlling ecosystem productivity, as well as being indicators of eutrophication caused by external stressors (e.g., atmospheric deposition or visitor use activities). Nitrogen will be measured as total dissolved nitrogen (TDN), dissolved inorganic nitrogen (DIN), and dissolved organic nitrogen (DON). We will analyze TDN and DIN directly through chemical analyses, but DON will be estimated by the subtraction of the inorganic fraction (DIN) from the total portion (TDN). Total dissolved nitrogen is defined as both organic and inorganic nitrogen that is not retained on a 0.45 µm pore filter. For the purposes of this monitoring protocol, DIN is assumed to be made up of nitrate (NO_3^-) and nitrite (NO_2^-), ignoring potential contributions of ammonium ions (NH_4^+) (see below). By subtracting DIN from TDN, we will estimate dissolved organic nitrogen. By tracking status and trends in the three forms of nitrogen, we will more likely detect stressors associated with this nutrient. Ammonia was also considered, but was below quantifiable limits in most cases (Appendix A) and analytical requirements of quick processing would be logistically difficult for backcountry lakes.

Similar to nitrogen, phosphorous is an important limiting nutrient and can be the most limiting. We will be monitoring total dissolved phosphorous, which is organic and inorganic phosphorous that is not retained on a 0.45 µm pore filter.

For both nitrogen and phosphorous, a derived metric, Trophic State Index (TSI), will be calculated to give estimates of the trophic status of the ecosystem (e.g., eutrophic or oligotrophic) (Carlson 1977, 1992).

Oxidation/reduction potential, or redox potential (hereafter), is a measure (or expression) of the oxidizing or reducing intensity of the water column (Wetzel 2001). This refers to the oxidized (loss of electrons) or reduced (gaining electrons) state of chemicals, especially iron and manganese. There is a tendency for reduction to be associated with anoxic conditions, so that stratified lakes will have sharp changes in redox potential. This is because oxygen is an oxidizing agent. Redox potential dictates the ionic charge state of nutrients, some being biologically available and others being unavailable for metabolic purposes. Generally, if a lake is most oxidizing (has a positive redox potential), inorganic waste products from biological processes will be oxidized, changing ammonia into nitrates. Likewise, the reducing zones of a lake are important in denitrification processes. Changes in redox potential are also associated with the trophic condition of lakes, with oligotrophic lakes having higher oxidation, and hypereutrophic lakes being reduced.

Turbidity is a measure of the clarity of the water column. Water with high turbidity (e.g., low clarity) indicates either high amounts of suspended solids (i.e., siltation) or high productivity. Oligotrophic, montane lakes should have low turbidity. Trends in turbidity will indicate shifting changes in land use activities that may impact water quality, or increasing nutrients that may increase productivity and lead to changes in lake trophic status.

2.5.3 Lake Environmental Parameters

Environmental measurements serve as co-variables to help us understand patterns in the aquatic communities and also as monitoring parameters themselves. As co-variables, environmental variables are useful in predicting presence/absence of organisms based on habitat heterogeneity or on total habitat availability and may help explain important spatial variation in other parameters of interest across the sampling frame. They are important components of aquatic resource monitoring because these characteristics help describe the context or template for ecosystem function and condition (Southwood 1977, Warren 1979, Frissell et al. 1986, Larson et al. 1994, 1999). Additionally, as monitoring parameters of their own, trends in specific parameters (e.g., increases in the percent of fine sediments) can indicate a stressor such as land use or visitor impacts. Changes in lake area can also be indicative of reduced water availability (a potential effect of climate change).

Percent substrate type is a measure of the habitat heterogeneity of a lake or pond. The substrate also denotes a “quality” of the ecosystem that influences the aquatic communities (Minshall 1984). Substrate type will be measured using a hand-held Global Positioning System unit, to produce a fine-scale map of substrate types that can also be used to determine total amount of substrates (e.g., X# of meters of cobble or silt). Taken together, the substrate types will convey information about total habitat heterogeneity for all lake organisms.

Area of the site (measured around the circumference at the wetted perimeter) is a basic measure of total habitat availability. The larger the wetted area, the more species that the lake may be capable of supporting (MacArthur and Wilson 1967), whereas a smaller wetted area may contribute to the lake being more susceptible to changes in the water cycle, i.e., becoming ephemeral with reduced snowpack and precipitation. Area will be measured using a hand-held Global Positioning System unit, to produce a fine-scale areal outline. When entered into a Geographical Information System software (i.e., ESRI Arc products), other ecosystem measures will be generated, such as the longest length and width.

Shoreline length is the circumference of the lake wetted perimeter, also to be determined in the field with a Global Positioning System unit.

Water clarity is a basic measure of water quality and trophic status of a lake or pond. Generally, the less clear the water is, the higher the productivity is. Trends in water clarity can be extremely useful as an independent measure to nutrients chemistry and Chlorophyll *a* measures as a method of detecting eutrophication of lentic habitats. Similar to nutrients, water clarity measurements can be used to derive a Trophic State Index (Carlson 1977, 1992). Water clarity is measured using a Secchi Disk in the field. Lower Secchi depth readings will correlate with higher turbidity, and although turbidity will be a more sensitive reading, the collection of Secchi depths will allow broader comparisons to patterns nation-wide (many volunteer organizations use Secchi depths for citizen monitoring). Secchi Disk readings, however, will not work at shallow sites where the disk is visible to the bottom of the lake, so they will only be taken and recorded at lakes deep enough for the Secchi Disk to disappear.

2.5.4 Aquatic Communities

The aquatic community of a lake is made up of different taxonomic components, spanning the spectrum of functional roles: primary production, consumption, predation, and decay. Here, we take the view that any one taxonomic component (e.g., zooplankton) is not a “community,” but rather an assemblage that makes up an important part of the entire aquatic community. By sampling all aspects of the aquatic community, we will effectively be sampling the food chain (or trophic web) of the lake, allowing the determination of status and trends in the functional ecology of the lake or pond. By examining the whole aquatic ecosystem, interactions between organisms can be better understood so that predictive models of how the park ecosystems will respond to specific stressors or extirpations can be evaluated (Agrawal et al. 2007).

Aquatic communities are important components of healthy aquatic ecosystems that are determined by and sensitive to the conditions of the habitats within which they reside (Loeb and Spacie 1994). Part of their utility as monitoring indicators is that each assemblage can react to different stressors individualistically. For example, an increase in sediment inputs can create negative responses in fish due to clogging of gills, whereas certain insects (e.g., certain Chironomidae midges) will respond positively to an increase in fine sediments. An additional advantage is that aquatic communities can integrate responses to stressors over time, with some components responding rapidly to changes, and others responding gradually to longer-term stressors. For instance, benthic macroinvertebrates act as continuous monitors of water quality issues, so that even a point-in-time measurement can provide information about seasonal or annual trends without the need for continuous sampling (Hawkes 1979).

Integrated biological sampling provides cost-effective monitoring of aquatic resources, when compared to other types of monitoring. A review of cost/benefits comparing biological monitoring to physical, chemistry, and toxicity monitoring showed the greatest gain and understanding from using biomonitoring alone, and that when combined with physical and chemical monitoring, provided the best overall assessment of the ecosystem (Brinkhurst 1996).

Chlorophyll a is a measure of algal productivity and can also be used in Trophic State Index model (Carlson 1977, 1992). Chlorophyll *a* concentration can be affected by an increase or decrease of nutrient input into a system, with increases in Chlorophyll *a* being a consistent response to increased nutrients. In terms of examining the trophic web of the lake, Chlorophyll *a* is a useful proxy for lake primary production. Direct measurements of the pelagic algal community, the phytoplankton, are not measured due to budgetary constraints.

Zooplankton are important members of lake communities. As an individual monitoring component, techniques for analysis and interpretation are still being developed such as ecological measures of integrity and classification based on zooplankton assemblage (Boix et al. 2005). Zooplankton indices have also been successful in detecting trends and ecological condition of wetlands (Lougheed and Chow-Fraser 2002). By combining zooplankton assemblage data with the other components of the aquatic communities, a robust image of the ecological integrity can be developed (Knapp et al. 2005).

Benthic macroinvertebrates have a rich scientific history as biomonitoring tools (Rosenberg and Resh 1993). Change in this diverse group of aquatic organisms has been demonstrated successfully as indication of ecological impairment (e.g., Lenat et al. 1981, Rosenberg et al. 1986). Benthic macroinvertebrates have formed the basis of predictive models of impairment, using O/E (observed to expected ratios) to compare existing with expected conditions. Such predictive models include the River Invertebrate Prediction and Classification System (RIVPACS, Wright et al. 1989) models, but also integrated multi-metric IBIs and IEIs (indices of biological and ecological integrity, respectively) (Karr and Chu 1999). Our intention is to develop similar models for lakes.

Amphibians are perhaps the premiere "early-warning detection system," in the sense that they are exceptionally sensitive to changes in the water chemistry, chemical pollution, and introduced pathogens. Amphibians world-wide are experiencing population declines due to a large number of distinct and interacting stressors (e.g., exotic species, impaired habitat, pollutants, climate change, etc.). For this reason, many populations are currently imperiled and necessitate monitoring for inherent conservation reasons. Integrated into the lake/pond monitoring, amphibians represent signals of introduced exotic species (Stead et al. 2005, Fellers et al. 2008), emerging wildlife diseases (Collins and Storfer 2003), and declining ecological integrity (Knapp et al. 2005).

Fish are also useful for documenting ecosystem response to stressors. Moreover, as the top predator in the lentic ecosystem, trends in fish populations can indicate large, cascading effects throughout the ecosystem (Power 1990). In the case of LAVO, fish are an interesting conundrum, in that they are introduced and are hence a stressor themselves. Monitoring fish populations can then both serve as indication of ecosystem response to far field stressors and as a direct measure of a specific local stressor itself.

2.5.5 Derived and Integrated Metrics/Indices
From the various classes of monitoring parameters, we will derive a number of useful metrics and indices for assessments of status and trend, as well as data exploration (Table 6). Some metrics are used as simple correlative parameters (e.g., approximate volume) for classification or data exploration; other metrics serve as explanatory variables (e.g., shoreline development), which should equate to habitat complexity (Wetzel 2001). The actual calculation of these metrics is detailed in SOP #19: Data Reporting and Analysis.

Table 6. Derived metrics and indices to be used in further data analysis, co-variables, or status and trend analyses. For ecological indices, letters in parentheses indicate taxonomic groups that will be used for that index (F = Fish, MI = Macroinvertebrates, Z = Zooplankton, A = Amphibians, All = all groups to be used simultaneously).

Derived calculation	Type	References
Approximate volume	Morphometric	Wetzel 2001
Shoreline development	Morphometric	Wetzel 2001
Trophic state index	Ecological	Carlson 1977, 1992
Shannon Index (F,MI,Z)	Ecological	Magurran 2004
Evenness (F,MI,Z)	Ecological	Magurran 2004
Hilsenhoff Biotic Index (MI)	Ecological	Hilsenhoff 1987, 1988
Fish Condition Index (F)	Ecological	Anderson and Gutreuter 1983
Observed/expected ratio (MI,Z,A,All)	Ecological	Knapp et al. 2005
Index of Ecological Integrity	Ecological	Karr and Chu 1999

Approximate volume is a calculated value based on the assumption that the lake has a cone-like bottom profile (or hypsographic curve). We use this approximation as opposed to the more costly and logistically difficult procedure of detailed bathymetric maps.

Shoreline development is the ratio of the actual shoreline to that of a circumference of a perfect circle of the same surface area. A perfectly round lake will approach 1, whereas a lake with a complex shoreline will have higher numbers of shoreline development. This metric is a reflection of the possibility of increased development of littoral communities, proportional to the lake size.

Trophic State Index is a concept developed by Dr. Robert Carlson, where algal biomass (measured as Chlorophyll *a*), clarity, and nutrients are used to either directly assess the state of oligotrophy, mesotrophy, or eutrophy of a water body directly (using algal biomass) or indirectly using proxies (Secchi depth and nutrient chemistry).

Shannon index and *Evenness* are classical measures of diversity that incorporate dominance, or lack of dominance, of taxonomic groups. We use these in addition to normal measures of diversity, such as basic species richness, because macroinvertebrate responses to stressors are often manifested as dominance changes, with one or two species dominating the assemblage. In these cases, Shannon index and Evenness may provide more power to evaluate stressor response of the aquatic community.

Hilsenhoff Biotic Index is a weighted average of tolerance values derived from empirical observations of macroinvertebrate responses to pollution (Hilsenhoff 1987, 1988). Because these responses have been extended to a variety of impacts, the Hilsenhoff Biotic Index is a useful way of examining macroinvertebrate changes to stressors. Recent work has also tried to adapt zooplankton to tolerance values (Lougheed and Chow-Fraser 2002). As a body of literature is built, we will expand the use of the Hilsenhoff Biotic Index to zooplankton.

Fish Condition Index is based on the ratio of fish weight to length (LeCren 1951), with the basis that fish that have higher weight to length ratios are "healthier" than fish with low ratios.

2.5.5.1 Multi-metric Indices of Ecological Integrity (IEI): The first Annual Report will develop park-specific Indices of Biological Integrity and an Index of Ecological Integrity. Integrated measures that collate information from different parameters are a useful and powerful tool in biological monitoring (Karr and Chu 1999). These multimetric methods employ a variety of parameters to develop a single index of environmental quality. For example, some of the metrics used in macroinvertebrate-based Index of Biological Integrity (IBI) are based on the following categories: 1) taxa richness and composition; 2) tolerant vs. intolerant organism; 3) feeding and habitat requirements; and 4) population attributes. Integrating measures from all four parameter categories results in a robust measure of ecological integrity.

In this protocol, we will develop park-based IBIs (Indices based on strictly biological data) and an IEI, where we incorporate physical and chemical metrics into the overall model, if appropriate. More detail on the process of developing IBIs and IEIs are given in SOP #19: Data Analysis and Reporting.

2.5.5.2 Observed/Expected Ratio: The RIVPACS (River Invertebrate Prediction and Classification System) is a metric that compares the Observed value (of species richness) to an Expected value. It is calculated as:

$$RIVPACS\ Score = \frac{Observed\ no.\ of\ taxa}{Expected\ no.\ of\ taxa}$$

The intuitive, easily explained nature of the score and its interpretation is one of the main advantages for using RIVPACS. For example, a score of 0.85 for a site can be interpreted as a site that had 85% of the expected species (i.e., depauperate, perhaps has experienced local extirpations of biodiversity). Likewise, a score of 1.15 indicates that a site had 15% more taxa than expected (i.e., site is of exceptional quality and is supporting a diverse community).

The RIVPACS bioassessment procedure has been extensively developed and refined over the years. The procedure has been extensively utilized by many agencies and predictive models already exist for streams throughout the western United States (United States EPA 2006). But as the name implies, it has been focused on river bioassessment programs. However, recent work has been accomplished applying the methods successfully to lake communities (Johnson 2003, Knapp et al. 2005).

The second Analysis and Synthesis report will focus on developing RIVPACS O/E type scores to park unit lakes. More details on the methods needed for developing O/E scores are presented in SOP #19: Data Analysis and Reporting.

2.6 Power Analysis and Level of Change that can be Detected

Power analysis (statistical power of a hypothesis test) in a long-term monitoring program is an important issue to consider. It is extremely necessary to ensure that monitoring can actually assess environmental changes at a level that is relevant to managers. However, evaluation of a power analysis must recognize several aspects: (1) power is affected by three quantities: α, the probability of a Type I error (rejecting the null hypothesis, when the null hypothesis is true); the practically significant difference (degree of change [effect size] of interest for management); n, the sample size; and σ, the amount of natural variability in the population; and (2) types of tests can affect power (e.g., a *t*-test versus regression, and a one-tailed *t*-test versus a two-tailed *t*-test).

Power is defined as $1 - \beta$, and β is dependent upon the actual effect size (or actual change in the measured parameter), which the investigator does not know prior to experimentation or sampling. Hence, a power analysis investigates a range of effect sizes and determines what the power is under a hypothetical effect size, so that a “power curve” is developed. Alternatively, the investigator can specify the desired effect size to detect and evaluate power at that level of change; this is the tactic employed in this analysis. For a specific test of interest, one quantity can be solved for by holding all others fixed. For example, in this protocol we are interested in solving for the power for a given sample size, magnitude of change, α-level, and estimated variability such that we can evaluate which parameters may be more sensitive for trend detection. Such pro-active (or *a priori*) power analysis allows us to evaluate the likelihood of successful trend or change detection for our sampling design. To do this, the model of holding sampling size constant, making estimates of our variance from our pilot project data, and then calculating hypothetical power is the most appropriate for judging the merits of our protocol plan.

Our power analyses are based on the following: (1) data from the pilot project (Appendix A) used to estimate population standard deviation; (2) α level of 0.10 (increased from the standard level of 0.05), using the justification that the “conserver’s risk” (e.g., the Type I error) should be less restrictive (Irwin 2004) given the mandate of the National Park Service to manage for future generations; and (3) the given desired effect size is a 20% change in any parameter. Both the α level and 20% effect size are somewhat arbitrary, although once chosen, α should remain unchanged. An effect size of 20% has been chosen as a reasonable goal because if detected, this level of change is probably a “biologically” significant increase or decrease that may signal need for management actions.

2.6.1 Power Analyses Caveats

The goal of this protocol that is most relevant to power analyses is to **“**Characterize the habitat, water quality, and biotic communities in a probabilistic sample of mountain lakes and determine status and trends in key univariate and multivariate variables.” However, in determining trends using a linear regression model, the sample size that determines power for trend significance is the number of sampling periods. Hence, low power is a fundamental aspect for the *start* of a monitoring program (Morrison 2007). It is only after many sampling periods that power to detect trends is accomplished. Furthermore, statisticians are still developing techniques for trend detection that integrate separate panels in a split-panel revisit design, as employed in this protocol (US Environmental Protection Agency, A. Olsen, Environmental Statistician, electronic mail, 13 March 2009). The split-panel revisit design was largely developed for status assessment, which does not require a “power analysis.” On account of this, our power analyses do not address long-term trend detection, but rather a shift in a parameter between only two sampling occasions (a two sample *t*-test). This is a rather simplistic assessment of power; evaluation of the strength of a monitoring program should recognize that a regression analysis (when a gradient exists) is *more* “powerful” (Somerfield et al. 2002). Over the long term, the “power of the protocol” is going to be greater than presented here.

Second, many of our protocol objectives focus on a multivariate approach because we have chosen to analyze community change using species assemblages. Primary methods for the analysis of community data are non-parametric methods, for which there is no theoretical basis for power analyses (Somerfield et al. 2002). In other words, it is impossible with the current body of statistical literature to run power analyses on our primary method of data analysis. The utility of using univariate measures to assess a sampling program based on multivariate analyses is summarized by Somerfield et al. (2002):

“Multivariate techniques have been shown repeatedly to be more “sensitive” (i.e. powerful) than univariate techniques (Warwick and Clarke 1991, Somerfield and Clarke 1997, Clarke and Warwick 2001) and although there is no general framework for determining power in the multivariate context the repeated demonstration that multivariate technique produce significant results when univariate techniques do not may be taken as evidence that a survey designed to have adequate power in a univariate context (e.g. for diversity indices) should have adequate power in the multivariate context (of changes in whole community composition).”

Third, many of our variables are measured to provide context for other parameters. For example, anions and cations are measured to understand lake chemistry in relation to the zooplankton and Chlorophyll *a* biomass but not as parameters for trend detection by themselves. So, although some parameters may have extremely low power due to high variability, this does not limit their usefulness for the monitoring program.

2.6.2 Water Chemistry Power Analyses

Measurements made during the pilot project at LAVO were used to estimate the power to detect a hypothetical 20% shift (increase or decrease) in the value between two sampling periods (Table 7). Power was based on one sample, 2-tailed *t*-tests using pilot project data. Values were split between shallow samples (taken at 0.5 m below the water surface) and deep samples (0.5 m above the lake bottom). In cases where the lake was less than 2 m deep, a single middle sample was taken.

Power was relatively low in both shallow and deep samples (average of 41% and 43%, respectively). Some parameters uniformly had high power (e.g., ammonia), whereas some had low power (e.g., sodium). A higher power for parameters taken in the middle of the water column demonstrates the importance of measuring secondary habitat variables. Variability within these lakes was lower, possibly because the habitat was more similar (i.e., they were all shallow lakes with max depth under 2 m). Contrasted to lakes where a deep and shallow sample was collected, the range of lake depths were from 2 m to 25 m, with a correspondingly lower power.

Although some of these powers are low, their main purpose is as explanatory and co-variables to other measurements (e.g., biological parameters). In the synoptic sampling design of this protocol, we do not expect to have the power to detect minor shifts in these parameters measured every 3 years.

Table 7. Results of pilot project measurements in the summer of 2008 from Lassen Volcanic National Park, and power analyses calculated from averages and standard deviations. Power was based on 1-sample, 2-tailed *t*-tests, with the measured pilot project mean, and standard deviation, run against a hypothetical mean representing a 20% change. Hypothetical sample size was 30. Analyses were run in Systat 12. All values (except power) are in mg/L. n in table refers to number of samples from pilot project that average and standard deviation were based on. -- indicates not enough samples (did not meet minimal quantification levels, or rejected for QC purposes).

	Shallow Sample (n = 16)			Middle Sample (n = 4)			Deep Sample (n = 16)		
Measurement	Average	Standard Deviation	**Power**	Average	Standard Deviation	**Power**	Average	Standard Deviation	**Power**
Total Nitrogen	0.318	0.189	**57%**	0.513	0.094	**100%**	0.323	0.181	**60%**
Total Phosphorous	0.015	0.012	**40%**	0.029	0.011	**90%**	0.016	0.014	**31%**
Nitrate-Nitrite	0.007	0.008	**24%**	0.003	0.001	**100%**	0.005	0.003	**53%**
Ammonia	0.016	0.004	**99%**	--	--	**--**	0.016	0.005	**97%**
Sodium	1.229	1.768	**19%**	0.848	1.073	**22%**	1.297	1.838	**20%**
Potassium	0.492	0.453	**32%**	0.208	0.042	**100%**	0.474	0.451	**30%**
Calcium	4.427	12.730	**12%**	1.470	2.119	**19%**	4.669	13.025	**13%**
Magnesium	1.013	1.354	**21%**	0.535	0.602	**25%**	1.047	1.387	**20%**
Sulfate	4.548	16.256	**12%**	0.023	0.023	**29%**	4.506	16.118	**12%**
Chloride	0.239	0.079	**94%**	0.190	0.032	**100%**	0.275	0.158	**59%**
Chlorophyll *a*	0.568	0.512	**33%**	--	--	**--**	0.506	0.269	**65%**
Dissolved Organic Carbon	4.806	3.410	**45%**	5.100	1.044	**100%**	3.259	1.860	**59%**
		Average	**41%**		Average	**68%**		Average	**43%**

2.6.3 Biological Power Analyses

Summary indices derived from zooplankton and macroinvertebrate samples were used to conduct prospective power analyses on the biological community (Table 8). For both zooplankton and macroinvertebrates, species richness (S) and Shannon index (H') were used to assess power to detect a 20% change between sampling periods (SOP#19: Data Analysis and Reporting details how S and H' are calculated). Analyses were done as above for water chemistry, with the exception that there was no need to separate out depths (all samples were taken in the water column [zooplankton] or littoral zone [macroinvertebrate]). Power was high for macroinvertebrates (99% - 99.5%) and reasonable for zooplankton (74.6% - 82.7%). Both species richness and Shannon index are relatively coarse measures for detecting trends, but the ability to confidently assess change in even these rudimentary characteristics suggest that more robust analyses (e.g., ecological ordination, Analysis of Similarity, etc.) will be able to detect trends.

During the pilot project, fish were only collected in two of the 21 lakes sampled. In Summit Lake, we collected five Brook Trout, (*Salvelinus fontinalis*) and in Reflection Lake, we collected 23 Golden Shiner (*Notemigonus crysoleucas*). Although these samples do not lend themselves to a park-based trend, we analyzed *K*, the condition factor of each species to determine our ability to detect trends in *K* at individual lakes (SOP #19: Data Analysis and Reporting details *K* calculation) (Table 9). We assumed that a repeat sampling would result in the same sample size (in number of individual fish collected). Power was high for both species.

Table 8. Results of power analyses on macroinvertebrates and zooplankton using 1-sample, 2-tailed *t*-tests to detect a 20% change in Species richness and Shannon index. Averages and standard deviations were calculated using pilot project data. Analyses were run in Systat 12.

	Macroinvertebrates			Zooplankton		
Index	Average	Standard Deviation	**Power**	Average	Standard Deviation	**Power**
Species richness	28.60	7.20	**99.5%**	13.9	5.75	**82.7%**
Shannon index	2.16	0.59	**99.0%**	1.17	0.57	**74.6%**

Table 9. Results of power analyses for site assessment of 20% change in fish condition factor, *K*. Analyses were run in Systat 12 using a 1-sample, 2-tailed *t*-test, with the assumption of follow-up sampling returning the same sample size (n) for each lake. Note that this is for *site* assessment, not park assessment; only 2 of the sampled lakes had fish, limiting our inferences to the specific lake, and not the entire park unit.

K, Fish condition factor	Average	Standard Deviation	**Power**
Brook Trout (Summit Lake, n = 5)	1.78	0.218	**91%**
Golden Shiner (Reflection Lake, n = 23)	1.71	0.318	**100%**

2.6.4 Power Analyses Summary

In sum, power analyses to assess our minimal detectable difference for trend analysis are complicated by (1) sample size for trend is time periods sampled, not number of sites; (2) linear regression integrating split-panel designs are problematic (Starcevich 2009); and (3) our main statistical technique will be using non-parametric multivariate analyses, which are not amenable to power analyses at this time. Finally, the main parameters from the biological sampling will be observed/expected ratios (O/E) and indices of biological and ecological integrity (IBIs and IEIs), which will be developed later in the sampling program.

Regardless, power analyses to detect a 20% change between two time periods show mostly low power for chemical parameters but relatively high power for the biological community metrics.

3.0 Field and Laboratory Methods

3.1 Data and Sample Collection

The attached Standard Operating Procedures (SOPs) describe field collection methods in detail, including pre-season preparation, water sampling and handling, physical habitat sampling, aquatic community sampling, shipping of samples, and end of season procedures (Table 10).

Table 10. Standard Operating Procedures covering the preparation, collection, and recording of field data for the integrated aquatic community and water quality sampling of lakes.

SOP	Title and Description
SOP #1	**Preparations, Equipment, and Safety**
	This SOP is a general overview of the steps necessary for the initiation of a field season. It covers tasks that the Project Lead will have to start early on in the planning process: hiring of field crews, equipment preparation, scheduling of crews, and basic safety is discussed.
SOP #2	**Field Crew Training**
	This SOP covers the requirements for getting crews trained for the upcoming season, including field sampling procedures, ethical considerations, and data entry training.
SOP #3	**Site Selection**
	This SOP is provided to give an overview of the site selection process and to inform the field crews of how the sites were initially selected, but this protocol will only have to be performed once at the initial implementation of the program.
SOP #4	**Order of Work**
	This SOP covers the sequential order of the tasks that the field crew will perform, so that sampling is not compromised by previous tasks (e.g., trying to measure water clarity after stirring up sediments from macroinvertebrate collection.)
SOP #5	**Site Arrival Tasks**
	This SOP describes the initial on-site arrival tasks of the field crew: e.g., equipment set-up and associated tasks.
SOP #6	**Weather, Physical Habitat, and Site Photography**
	This SOP describes the steps for recording weather, immediate physical habitat descriptions, and digital documentation of a site.
SOP #7	**Fish Collection and Processing**
	This SOP details the procedures for setting gill nets, collecting and processing fish, guidelines on for the proper handling of fish, and data recording of the sampled fish assemblage.
SOP #8	**Water Sample Collection**
	This SOP describes the procedures necessary for collecting water samples at the deepest point in the lake and how to measure the water clarity with a Secchi disk.
SOP #9	**Water Sample Filtration and Handling**
	This SOP covers the steps necessary for field handling of water chemistry samples, including labeling, filtering, and storage. It also covers the process of Chlorophyll *a* sampling and field alkalinity measurements.
SOP #10	**Multiprobe Calibration and Use**
	This SOP covers how to calibrate and use the water quality multi-probe sonde for the collection of turbidity, temperature, pH, conductivity, redox potential, and depth using the Eureka Environmental Manta probe and Amphibian data recording unit.

Table 11. Standard Operating Procedures covering the preparation, collection, and recording of field data for the integrated aquatic community and water quality sampling of lakes (continued).

SOP	Title and Description
SOP #11	**Amphibian, Invertebrates, and Lake substrate walk-around**
	This SOP describes the integrated procedures for a lake walk-around for sampling macroinvertebrates, amphibians, and recording habitat type into a Trimble GPS unit. Embedded within these methods are the measurement of other physical parameters: habitat area, shoreline circumference, longest length, etc.
SOP #12	**Post-Site Tasks**
	This SOP details the necessary steps for the field crew required prior to leaving the site, including data quality control checks and disinfection procedures for wildlife diseases (e.g., Chytrid fungus) and exotic organisms (e.g., New Zealand mudsnails, *Potamopyrgus antipodarum*).
SOP #13	**Data Entry**
	This SOP covers the steps associated with entering the data collected during the field season and how to enter it accurately into the Klamath Network Lakes database.
SOP #14	**Photo Management**
	This SOP details the steps necessary to manage the digital images collected during the field season.
SOP #15	**Post-Field Season**
	This SOP describes tasks to be undertaken by the field crew at the end of the season, including equipment clean-up, inventorying, storage, and post-season de-briefing.
SOP #17	**Data Transfer, Storage, and Archive**
	This SOP describes how to transfer data from field sheets and electronic field equipment (Amphibian, GPS, and Camera) into the Klamath Network aquatic database along with storage of seasonal data and data archiving processes.

3.1.1 Field Season Preparation

It is imperative that preparations for the field season starts by January of the year that sampling will take place. The preparation should start with the hiring of the field crew. Ideally, the positions will be announced in January, so it may be necessary to have Human Resources start the procedure in the previous December. Other preparations that should be arranged prior to the start of the season include arranging for permits and housing for field staff.

Permit requirements may change from sampling period to sampling period, depending on locations of lakes to be sampled and the requirements of the current park staff. Some parks require permits while some will allow research and collections by National Park Service employees without a permit. Minimum Requirement Analysis for sampling in wilderness areas will need to be conducted. The Project Lead will need to coordinate with the Chief of Natural Resources at CRLA, LAVO, and REDW well in advance of the beginning of the field season to ensure that all permits are secured.

Sampling permits for fish are also necessary from the California Department of Fish and Game for the sampling of Freshwater Lagoon because half of the lagoon is located on state land. The permit procedure is available at: http://www.dfg.ca.gov/licensing/pdffiles/fg1379.pdf or by contacting:

DFG
License and Revenue Branch

1740 North Market Boulevard
Sacramento, CA 95834

All reporting requirements for park or state permits are the responsibility of the Project Lead.

3.1.2 Field Work

Crews hike or drive to collection sites. Crews work along the shoreline, wading into the shallow zones of the lake either in waders or neoprene booties as conditions warrant. The deeper portion of the lake is accessed using a lightweight, inflatable raft. Crews will be carrying heavy loads into the backcountry; lightweight personal and sampling gear is encouraged. This is especially important because the sampling frame has placed an emphasis on lakes that are accessible and can be sampled in a single day of travel. No overnight camping in the wilderness should be necessary, but will be encouraged if it facilitates sampling multiple sites efficiently.

Crews will collect water samples, physical habitat data, filter samples (e.g., Chlorophyll *a*), invertebrates, and fish samples. Invertebrate samples will be sent to an aquatic entomology laboratory but fish samples will be processed and disposed of in the field. Amphibians will be sampled using Visual Encounter Surveys. Amphibians will be handled only occasionally, as necessary to confirm species identifications.

Crews will perform alkalinity analyses in the field, using a portable test kit with minimal chemical requirements (mild sulfuric acid). All generated waste will be carried out by the crew, and disposed of properly, meeting requirements of the Chemistry Department of Southern Oregon University.

3.1.3 Sample Handling and Shipping

All staff handling samples are required to adhere to quality control procedures to ensure sample integrity. All procedures detailed in the SOPs must be performed. No “short-cuts” by the field crew will be allowed. Water samples must be placed in a designated freezer or refrigerator as soon as possible by the field crew upon return from the field. It is the responsibility of the Project Lead to secure access to such facilities by the field crew. Water samples are shipped overnight to the lab, using the Southern Oregon University administrative agreement to cover charges. Samples should be shipped early in the week, to avoid the potential for samples to show up at the end-of-week workday, at a time when no one is available to receive them.

Macroinvertebrate samples are stored in 95% Ethanol to ensure adequate preservation. It is the responsibility of the field crew to ensure that enough room in the sample vials exists to achieve this. All macroinvertebrate samples are retained by the Project Lead or field crew until the end of the season, when they will be shipped to an aquatic entomology laboratory. It is the responsibility of the Project Lead to ensure that samples are shipped legally (note: it is illegal to ship ethanol and other flammable liquids without special certification and training). The Project Lead should work with the aquatic entomology laboratory to meet these requirements. One possible solution to shipping Ethanol is the temporary replacement of Ethanol with water and overnight shipping. The aquatic entomology laboratory can than replace the water with Ethanol, so that minimal degradation to the samples has been incurred.

3.1.4 Quality Assurance and Quality Control

Quality assurance and quality control procedures are embedded in individual SOPs, so that if they are followed as written, the requirements of the Quality Assurance Project Plan (QAPP) will be met. Overall needs for the QAPP are reiterated in SOP#16: Quality Assurance Project Plan. The QAPP for Klamath Network lakes sampling have been written to meet the requirements of the National Park Service, Water Resources Division (Irwin 2004), the State of California Surface Water Ambient Monitoring Program Quality Assurance Program, and the Klamath Network Data Management Plan. The QAPP addresses the needs of measurement quality objectives, sample contamination, field measurements, sample handling, instrumentation testing and calibration, and audits.

3.1.5 End of Season Procedures

Once sampling is complete at all sites, gear is decontaminated a final time, cleaned, repaired as necessary, and stored. Crews will make a list of gear needing to be replaced or repaired.

The Project Lead will conduct a post-season debriefing with the field crew to discuss the season and make sure that all necessary sampling has been done. Any departures from the protocol will be discussed and analyzed. Necessary revisions and improvements to the protocols will be discussed.

3.2 Field and Laboratory Analyses

Laboratory methodologies and instrumentation have been chosen that match national standards, that are identical to methods used at CRLA, and that match the methods used by the North Coast and Cascades Network. With the exception of the measurements that will be made in the field (acid neutralizing capacity, temperature, dissolved oxygen, pH, conductivity, redox potential, and turbidity [Table 11]), all chemical analyses will be performed by contract laboratories (Table 12).

Field analyses and methodological details are presented in Table 11. A depth profile, measured at the surface and down every 0.5 m interval to just above the bottom substrate will be accomplished with a multi-parameter electronic recording unit (sonde), specifically the *Eureka Environmental Manta* multi-parameter sonde and *Amphibian* data recording unit. In keeping with the nature of a long-term monitoring program, the probe used may change as equipment wears out, technological improvements are made, and companies go in and out of business. Any change of equipment will follow the SOP#16: Quality Assurance Project Plan guidelines for cumulative bias, to ensure continuity of reliable data and documented using an equipment log book.

Table 12. In situ measurements, methods, and quality standards for depth profiles to be performed at the deepest location of the lake. Specifications from Eureka Environmental, www.eurekaenvironmental.com. NTU = Nephelometric Turbidity Units.

Measurement	Method	Range	Accuracy	Resolution
Depth	Pressure transducer	0 - 25 m	± 0.2%	0.01 m
Dissolved oxygen	Optical luminescence	0 - 25 mg/L	± 1% or 0.2 mg/L, whichever is higher	0.01 mg/L
pH	Reference electrode	2 - 12 units	± 0.2 units	0.01 units
Redox potential	Reference electrode	-999 - 999 mV	± 20 mV	1 mV
Specific Conductance	4-Electrode Graphite Conductivity Sensor	0 - 5 mS/cm	± 1%	0.001 mS/cm
Temperature	30k ohm thermistor	- 5° C - 50° C	± 0.1° C	0.01° C
Turbidity	McVan NEP9500 type	0 - 3000 NTU	<1% when under 400 NTU	0.1 NTU

The sole chemical analysis to be done in the field will be the determination of acid neutralizing capacity from the epilimnion (0.5 m below the surface of the lake) and hypolimnion (0.5 m above the lake bottom substrate). Acid neutralizing capacity measurements will be accomplished using a Hach Digital Titrator Model 16900, following Hach procedure 8203. The range of this test kit is 10 – 4000 mg/L as $CaCO_3$; accuracy of the Digital Titrator is ± 1% for samples within the range of the test; resolution is one digit (1 mg/L for most circumstances), titrating to a pH endpoint of 4.8. Although laboratory testing could improve the range and resolution, the logistical constraint of short holding times (<14 days) necessitate field analyses. A further consideration is the use of acid neutralizing capacity as a co-variable to examine the ecological integrity of the aquatic ecosystem and not as a single factor for trends alone. We maintain that it is more important to identify ecosystems with high versus low acid neutralizing capacities as a covariable and the accuracy and resolution of the Hach field kit will meet these needs.

Klamath Network and network park units do not have facilities, equipment, or personnel to conduct laboratory analyses in-house, necessitating the contracting to a specialized laboratory. In general, the procedures will follow those recommended by the American Public Health Association (Eaton et al. 2005) and approved by the US Environmental Protection Agency.

Table 13. Laboratory analyses to be conducted by a contract laboratory; minimum MDL, ML, and precision requirements. [1]= example instrumentation used by contract laboratory (Oregon State University CCAL) for pilot project. APHA = American Public Health Association (Eaton et al. 2005); MDL = Method Detection Limit; ML = Minimum level of quantification.

Parameter	Method	Instrumentation[1]	MDL (mg/L)	ML (mg/L)	Precision (± mg/L)
Calcium	APHA 3111 D	Varian SpectrAA220	0.06	0.19	0.06
Chloride	APHA 4110 B	Dionex 1500 Ion Chromatograph	0.01	0.03	0.01
Dissolved Organic Carbon	APHA 5310 B	Shimadzu TOC-VCSH Combustion Analyzer	0.05	0.16	0.05
Magnesium	APHA 3111 B	Varian SpectrAA220	0.02	0.06	0.02
Nitrate	APHA 4500-NO3 F	Technicon Auto-Analyzer II	0.001	0.003	0.001
Potassium	APHA 3111 B	Varian SpectrAA220	0.03	0.1	0.03
Sodium	APHA 3111 B	Varian SpectrAA220	0.01	0.03	0.01
Sulfate	APHA 4110 B	Dionex1500 Ion Chromatograph	0.02	0.06	0.02
Total Nitrogen	APHA 4500-NO3 F; APHA 4500-P J. Persulfate digestion	Total Technicon Auto-Analyzer II	0.01	0.032	0.01
Total Phosphorous	APHA 4500-P B; APHA 4500-P E	Milton-Roy 601 Spectrophotometer with 10 cm pathlength	0.002	0.003	0.002

4.0 Data Management, Analysis, and Reporting

The clear, concise, and consistent recording, analysis, and reporting of data is essential to the success of the long-term monitoring of Klamath Network lakes program and will be a top priority for all personnel involved in the monitoring program. During each phase of the monitoring effort, from planning to parameter assessment, sample collection, and sample processing, and including data entry, analysis, and reporting; standard quality assurance; and quality control, checks will be used to ensure the accuracy and completeness of monitoring program activities. Responsibilities for each person involved in the project are outlined in SOP #16: Quality Assurance Project Plan. Each person should be familiar with their roles prior to implementing field work. Guidance for data management and analysis (in general, and in the field and laboratory) are available from the Klamath Network Vital Signs Monitoring Plan and its attached Appendix J (the Klamath Network Data Management Plan), available at: http://science.nature.nps.gov/im/units/klmn/Monitoring/ MON_Phase_III.cfm. Additional guidance is available on the NPS Data Management web site at: http://science.nature.nps.gov/im/datamgmt/index.cfm and from EPA Guidance for Quality Assurance Project Plans (1998) available at: http://www.epa.gov/quality/qs-docs/r5-final.pdf. Specific SOPs covering the data management portions of these protocols are summarized in Table 13.

Table 14. Summary of SOPs covering aspects of data management, analysis, and reporting.

SOP	Title and Description
SOP #16	**Quality Assurance Project Plan**
	This SOP is a detailed description of the methods to ensure quality data, including QA/QC. Topics covered include chemical blanks, outlier analyses, data completion goals, roles and responsibilities, and ensuring data comparability over time.
SOP #18	**Metadata Guidelines**
	This SOP provides guidelines for the type of metadata to be collected and how it is stored and accessed.
SOP #19	**Data Reporting and Analysis**
	This SOP describes the methods for basic calculations of metrics and indices used in the protocol. It also details the reporting schedule for summary reports and Analysis and Synthesis reports.
SOP #20	**Revising the Protocol**
	This SOP details the steps necessary to revise the protocol.

4.1 Database Design

The water quality component of the Natural Resource Challenge (NRC) requires that all NPS networks archive any physical, chemical, and biological water quality data collected with NRC water quality funds in the NPS STORET (STOrage and RETrieval) databases. To assist in this process, networks have the opportunity to make use of a relational database patterned after the Natural Resource Database Template (NRDT) and developed by the Water Resources Division (WRD) called NPSTORET, or they can utilize any of the numerous databases already available as long as they can export that data into a format that meets the STORET Electronic Data Deliverable (NPSEDD) specifications. After analyzing the potential available databases and examining the utility of the NPSTORET database, the Klamath Network has opted to develop a NRDT compliant, network-specific database that meets the NPSEDD specification for all their aquatic and water quality monitoring projects. It was determined that NPSTORET did not have all the functionality needed to account of all the data being collected as part of this integrated protocol.

4.1.1 Metadata Procedures

A metadata record for the KLMN Lake Monitoring Database was developed. Creation of a metadata file is an integral part of any project that collects samples that generate data and information. Metadata consists of information that documents the information contained within data files and information products. The overall goals of metadata creation are to develop a comprehensive document that (1) explains enough about the project data to ensure they are useable by future personnel and the scientific community, and (2) complies with Federal Geographic Data Committee and NPS mandates for federal projects. Metadata development begins at the start of every project; as the project develops, so does the metadata. Within the sideboards set by the program and federal requirements, the process of metadata creation will vary depending on goals and objectives, funding, and scope of the project. It is the responsibility of the Data Manager to set forth the metadata requirements and the process used to create the metadata. These requirements are outlined in SOP# 18: Metadata Guidelines.

The metadata for a project should be created prior to implementing the field season and will need to be updated at the end of each field season. The Klamath Network utilizes a Metadata Interview form that describes the various attributes of a dataset. The interview form includes information about the time frame, description, sensitivity, collection location, and purpose of the data, plus various other pieces of information needed to develop the metadata for the dataset. It is the Project Lead's responsibility to complete a new Metadata Interview form before the start of the first field season and at the end of each additional field season.

In addition to metadata associated with each spatial product and database, the Klamath Network requires metadata to be provided for each photograph used to capture some aspect of a monitoring project (e.g., field crew, sites, sampling method). Photographs are a valuable tool used for a multitude of objectives including conducting outreach, identifying specimens, displaying habitat conditions, documenting field work, and analyzing data. It is the responsibility of the field crew and the Project Lead to follow the Klamath Network Photograph Guidelines available through the Klamath Network web site or by directly contacting the Network Data Manager. The Project Lead will submit project-related photographs and photograph metadata to the Data Manager at the end of each project.

4.1.2 Storage

When collecting data electronically in the field, a backup of the database will be made prior to leaving a field site. The backup of the database should be stored to a source that is external of the electronic device. Once out of the field, data from the electronic devices should be stored in a desktop or laptop computer. Backups should be placed in a separate folder that contains subfolders organized by date.

When returning to the Klamath Network office, data should be reviewed by the Project Lead. Once the data have undergone all validation and verification processes, they should be transferred to the Network Data Manager along with a data certification form. Once submitted, the data will be uploaded to a master database that can be used for data analysis. In addition, the data will follow the backup process implemented by Southern Oregon University that includes nightly, weekly, and quarterly backups stored for 2 months (nightly and weekly backups) or 1 year (quarterly backups).

4.2 Data Collection and Data Sheet Archival

The Klamath Network, when possible, will make use of tablet PCs, Trimble Pocket PCs, and/or PDAs to collect data associated with this protocol. It is the responsibility of the Field Crew Leader and Project Lead to adequately train field crews in data collection and management methodologies outlined in this protocol. Since this protocol is a long-term commitment and crew turnover is expected, a training session, based on the Data Entry SOP (#14) is necessary each season. A log should be kept outlining the training sessions each crew member attends, and logs should be transferred to the Data Manager at the end of each field season.

While the Network will make every attempt to enter data electronically in the field, we recognize there are instances when this will not be possible. Field crews should always have hardcopy field forms available when going to monitoring sites. If data are entered onto hardcopy forms, they should be entered into the database as soon as possible after data collection. Data entry should occur each week unless longer time frames are approved by the Project Lead and Network Data Manager. At no point should field notebooks be substituted for datasheets. Datasheets should be designed following the specifications outlined in the Klamath Network Data Management Plan (Mohren 2007). All datasheets will be bound and stored in a waterproof storage container at the end of a sampling day. At the end of a sampling period, upon returning to the Klamath Network office, datasheets will be scanned into a PDF format with a naming convention outlined in SOP #15: Post-Field Season. PDF documents will be stored in the project folder located on the Klamath Network server. Original datasheets will be stored in a dry, water-proof container at the Klamath Network office.

4.3 Data Verification and Validation

Data verification is the process of ensuring that data entered into a database accurately duplicate data recorded in the field. Field crew members should implement the following process to verify data:

1. Visual review at data entry— This method should always be used when entering data. In this method, the crew member entering the data verifies each record *after input*, prior to the next input. Records are checked to ensure all parameters have been entered and that the values make sense. If hardcopy datasheets are being used, records entered into the databases are compared to the data on the hardcopy datasheets. Errors or missing values are corrected immediately.

2. Visual review after data entry— After the data have been entered, and prior to leaving the site, records should be double-checked to ensure they are complete and accurate. When possible, this should be completed by someone other than the person who entered the data.

3. Final Review— After following the processes outlined in number 1 and 2 above, it is the Project Lead's responsibility to review a predetermined subset of records that have been entered into the database and compare them to the original hardcopy forms, if available. A timeline should be developed during the project's planning phase to outline the number of records that will be checked and a time frame as to when they will be examined.

While data verification can be completed by someone with little to no knowledge of the data, data validation requires a reviewer to have extensive knowledge on what the data mean and how they were collected. Data validation is the process of reviewing the finalized data to make sure the information presented is logical and accurate. The accuracy of the validation process can vary greatly and is dependent on the reviewer's knowledge, time, and attention to detail. General data validation procedures include:

Data entry application programming— Filters for illegal data will be used, when possible, to prevent data being entered that exceed their logical value (e.g., 2 m vs. 200 m stream depth). It is important to note that not all fields have appropriate domains and it will be the responsibility of the Project Lead to examine these fields for erroneous data.

Outlier detection and review— An outlier is an unusually extreme value for a variable, given the statistical model being used to analyze the data. It is important to note that not all outliers are a result of data contamination; they may be indicators of important thresholds or extremes in variation of the parameter of interest. Statistical tests such as Grubbs' test, regression mapping, and graphical displays such as scatter plots will be used to examine the data for outliers (Michener et al. 2000). Depending on the analysis methodology, outliers may not need to be removed. A determination will need to be made to define what is considered an "unusually extreme" value indicating data contamination or an environmental aberration that clouds the interpretation of the field measurement. Generally, non-error-associated outliers should be flagged and retained, allowing those conducting data analysis to make determinations about inclusion or rejection.

Review of what makes sense— The Crew Leader and Project Lead should be intimately familiar with the types of data being collected, including expected data ranges. The individuals in these roles should review the tabular data to make sure they appear logical. GIS data should be plotted and examined to determine the accuracy of the spatial locations (Sanders 2005).

4.3.1 Data Certification

After data validation and verification, the Project Lead will turn in a Data Certification form(s) (from the Klamath Network Data Management Plan, Mohren 2007) to the Data Manager. This form is used to ensure:

- The data are complete for the period of time indicated on the form.
- The data have undergone the quality assurance checks indicated in the protocol.
- Metadata for all data has been provided.
- Project timelines are being followed and all products from the field season have been submitted.
- The level of sensitivity associated with the deliverable is appropriate.

A new certification form should be submitted each time a product is submitted. If multiple products are submitted at the same time, only one form is necessary.

4.4 Data Analysis and Reporting

Data analysis and reporting guidelines are covered in SOP #19: Data Analysis and Reporting. This SOP covers a comprehensive approach by the Klamath Network of the reporting of data for the next 12 years. There will be two elements of our reporting strategy: (1) Annual Reports describing field sites visited, interesting findings, and status of the measured parameters completed every sampling period and (2) Analysis and Synthesis reports completed every 6 years that focus on trends and the development of indices. These reports and their contents are covered in more detail in SOP #19: Data Analysis and Reporting, but are briefly summarized here.

4.4.1 Annual Reports

Annual reports for this protocol are identical in format to annual reports for vital signs monitored every year. Since the lakes are only monitored 1 out of every 3 years, these reports are termed summary reports. An example of a summary report is provided in Appendix A, from the data collected during the pilot project. These reports will focus on providing managers a current status assessment, defined using measures of central tendency (means or medians) of the park habitats. Reporting tools will focus on mean conditions, along with user-friendly graphical presentations. Unusual or significant findings will also be highlighted. Annual reports serve to update the park units where sampling occurred for their use in management and reporting goals.

Due to necessary turn-around times for contract laboratories, summary reports will be due June 1st of the year following lake/pond sampling. This will provide approximately 180 days for the contract laboratories to process invertebrate and zooplankton samples and an additional 3 months for the Project Lead to complete the report. As appropriate, the report will be formatted to the Natural Resources Technical Report (NRTR) or as Natural Resource Data Series (NRDS).

4.4.2 Analysis and Synthesis Reports

Analysis and Synthesis reports form the basis of trend analysis for the integrated water quality and aquatic communities vital signs. In the spirit of long-term sampling, the protocol will run through several sampling periods before meaningful analyses can be completed. The first Analysis and Synthesis report will occur after the second sampling period, 6 years after implementation. As in the Annual Reports, they will occur every 3 years thereafter. Reporting format will follow the NRTR format.

The initial three Analysis and Synthesis reports will focus on describing the fundamental aspects and gradients of the lakes: (1) Physical, (2) Biological, and (3) Chemical. An individual report will be devoted to each aspect of the lake, starting with the least variable of the three: the physical environment. The second and third will focus on either the biological or chemical. The fourth report will be on the development of an Index of Ecological Integrity (as described above). This will be after four sampling periods, so that 75 (15 index and 60 survey) sites in LAVO will have been sampled and a reasonable sample size has been obtained. The emphasis for building the Index of Ecological Integrity will be the lake and pond ecosystems of LAVO. An index for CRLA will also be explored, despite a low number of sites (albeit replicated each year). With implementation in 2010, this report will be due on the 1st of November, 2020.

The fifth Analysis and Synthesis report will focus on the development of Observed/Expected Scores (or RIVPACS, as described above). This will be after five sampling periods, so that 90 total sites have been sampled. With implementation of the protocol in 2010, this report will be due on the 1st of November, 2023.

The sixth Analysis and Synthesis report will be the first major analysis of trends. This will be after six sampling periods and will be due on the 1st of November, 2026. Although this lag between implementation and the first trend analysis seems unduly long (16 years), this is close to the minimum number of sampling periods needed to achieve significant trends with the Mann-Kendall test at the α level of 0.05 level (Rohlf and Sokal 1995) (so trend analyses prior to this would be of limited usefulness). This report will be a comprehensive study on the techniques to detect trends and will outline the methods to be used in future trend analyses, recognizing that the field of ecological statistics and trend analysis will always be an innovative and evolving one.

Future Analysis and Synthesis reports after the development of RIVPACS and IEIs will always include a trend component. The Project Lead is encouraged to explore other aspects of monitoring as well. Possible topics include: (1) Bayesian statistics for lake management questions; (2) Status and trends in a regional context (i.e., integrating data from other regional programs); (3) Various lake/pond biology and ecosystem topics; and (4) Reanalysis of sampling frame (e.g., have new lakes formed or have perennial habitats become ephemeral). In determining the topics to be covered by Analysis and Synthesis reports, park staff at the respective park units should be consulted to explore specific management or research needs that may be answerable using the data from this protocol.

4.4.3 Data and Product Distribution

The Klamath Network utilizes the Network's Internet and Intranet web sites, Southern Oregon University, and the National I&M databases to disseminate information to the parks and the general community. Prior to dissemination, all spatial information must be associated with FGDC-compliant metadata. Documents should be in the proper format as described in the Klamath Network Data Management Plan. It is the responsibility of the Data Manager to work with the Project Lead and park staff to determine the sensitivity of the data prior to posting. Constraints will be placed on sensitive data to prevent or limit distribution to the public.

The Klamath Network will send raw field data from NPSTORET to the WRD on an annual basis for quality assurance and for upload into the WRD's copy of STORET and the Environmental Protection Agency's (EPA) STORET National Data Warehouse (Figure 6).

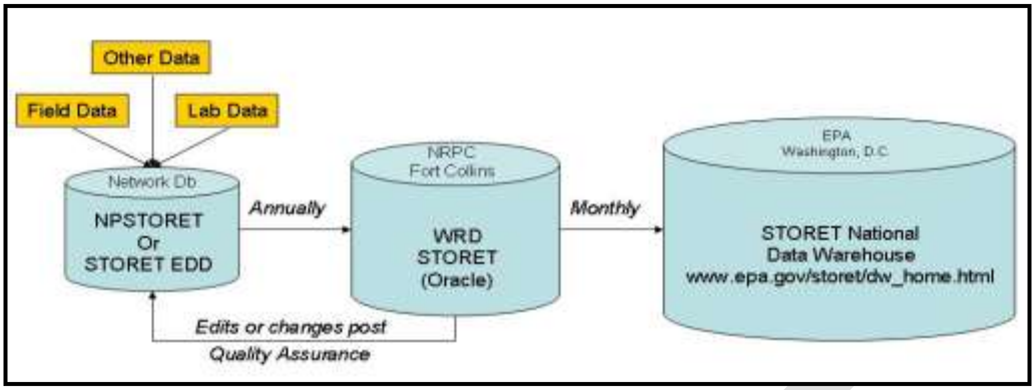

Figure 6. Simplified conceptual model of the Natural Resource Challenge vital signs water quality data flow from collection to distribution.

5.0 Personnel Requirements and Training

5.1 Roles and Responsibilities

The Integrated Aquatic Community and Water Quality Monitoring of Mountain Pond and Lakes in the Klamath Network program is the primary responsibility of the Network Aquatic Ecologist, also referred to as the Project Lead. The Project Lead is a GS-9/11/12 level scientist who is trained and experienced in aquatic ecology, with hands-on experience in lentic and lotic habitat ecology, either through postgraduate education or work experience. The Network Project Lead is responsible for managing the day-to-day activities of the lakes project; supervises seasonal crew members and provides them with tactical and logistical support during the field season; verifies, validates, and analyzes data; and writes and completes Annual (or Summary) and Analysis and Synthesis Reports.

Assisting the Project Lead are the Network Coordinator, who has overall responsibility for implementing and supervising the Klamath Network Mountain Pond and Lake Long-term Monitoring project; is responsible for the successful completion of all aspects of the program; and directly supervises the Network Project Lead and Data Manager. The Network Data Manager is responsible for creating and maintaining the seasonal and master database; providing data management guidance and training to project staff; and ensuring the data are accurate, properly documented, stored, archived in a secure manner, and made available to a diverse audience.

The field crew will consist of two members: a senior Field Crew Leader and a junior Field Crew Member. With the number of sites to be visited in this protocol at 42 or less (depending on the number of ephemeral ponds in CRLA), a single crew will be ample to sample all sites in the summer field season.

The Field Crew Leader is supervised by the Project Lead, is accountable for supervising crew members and any volunteers in the field, and is responsible and the successful completion and verification of monitoring program tasks. This includes but is not limited to the collection, storage, and shipment of field samples and the collection and entry of data into the monitoring program database. The Field Crew Leader also is responsible for the calibration, use, and/or maintenance of monitoring program instruments, equipment, and gear. The Field Crew Leader will have experience in conducting aquatic field work in relatively remote isolated locations, at least some minimum experience in supervising peers, and the ability to live and work cooperatively with others under often stressful and challenging conditions for extended periods.

The field crew member is supervised by the Field Crew Leader and will be responsible for successfully completing all monitoring program tasks, including but not limited to the collection, storage, and shipment of field samples and collection, verification, and storage of field data. The field crew members will have at a minimum some experience in conducting aquatic field work in relatively remote, isolated locations and demonstrate the ability to live and work cooperatively with others under often stressful and challenging conditions for extended periods.

5.2 Training Procedures

A standardized, comprehensive training program for all personnel is necessary to ensure that data collection is consistent and meets the data quality objectives of the Quality Assurance Project Plan (SOP #16: Quality Assurance Project Plan) and the data standards defined in the Klamath Network Data Management Plan. Consistency is the key to the successful accomplishment of the goals and objectives of this protocol. The training program should last 2 weeks, although actual data collection under the supervision of the Network Project Lead can be accomplished during this period.

The training program should start with classroom sessions, with the Project Lead developing a syllabus and instructional materials that adequately covers the following topics (the list can be expanded):

1. Background on I&M program objectives, sampling design, and data analysis.
2. Field sampling methods and QA/QC concerns.
3. Equipment operations and maintenance.
4. Field and laboratory sample processing and handling.
5. Fish and amphibian species identification, handling, and a primer on wildlife diseases.
6. Recording and storing data, both manually and digitally.
7. Safety in the backcountry.
8. Orienteering.
9. Backcountry rules and ethics.
10. Computer data entry.

This educational period is supplemented with this narrative, protocol, and appendices, but these materials (to be supplied before the Entrance on Date [SOP#1: Preparations, Equipment and Safety]) are not to be used as a substitute for a training period.

Classroom training material will be developed by the Project Lead and stored in electronic form on the Klamath Network server, following the protocols of the data management plan. Over the course of this protocol implementation, these materials will be refined and improved by the Project Lead.

After the classroom sessions have been completed, additional training will focus on hands-on collection of data in the field. This can take place at index sites within the appropriate park unit and be used as actual data for the program, with the qualification that the Project Lead is on hand to supervise and train the crew in proper techniques, to ensure QA/QC. For example, the Project Lead can take a profile reading with the water quality sonde as a demonstration, which will be actual data for the "record," which then will be repeated by the field crew members to learn the sampling techniques.

Each crew member will be certified in each SOP, with date certified, individual responsible for certification, and specific SOP certified recorded using the forms provided in Appendix F.

6.0 Operational Requirements

6.1 Annual Workload and Field Schedule

Necessary tasks for the implementation of this protocol are presented in Table 14. Preparation for the upcoming field season starts the year before, ideally in December or earlier. By January, the Project Lead should re-inventory and re-check the condition of the field gear and order replacements or send them to the manufacturer for servicing as necessary. (Checks will be done at the close of the last season, but with two years between sampling, gear must be rechecked.) In April, the Project Lead should obtain bids for specimen processing (water chemistry, Chlorophyll *a*, zooplankton, and macroinvertebrates) and initiate contracting to the chosen laboratory. Water chemistry bottles should be acid washed (or confirm that pre-acid washed bottles are ready in suitable numbers) and filters prepared for water sample collection (SOP #1: Preparations, Equipment, and Safety) in April, with all associated tasks completed by the middle of June. Training of the field crew should begin in July, at the start of the field season. Training is an on-going activity; periodic checks will be made to ensure that QA/QC procedures are followed. Although data entry will occur throughout the field season, a final QA/QC will occur with the presence of the field crew, so that any remaining questions may be answered. Upon data certification and receipt of the data deliverables of the specimen contractors, the Project Lead will formulate and write the Annual Report and/or Analysis and Synthesis report, as appropriate. The first stages of this could occur in October. However, initiation of the report writing may be delayed relative to the availability and delivery of the required data. Report(s) should be finalized by June of the following year.

Table 15. Summary of annual tasks and workload for implementation of protocol. N/A indicates not applicable, either an ongoing task, or open ended.

Task	Timeframe to initiate	Deadline
Hiring of Field Crew	December - January	End of January
Inventory and maintain field gear	January - February	End of February
Purchase required field gear	March	March
Acquire bids for specimen processing, arrange contracting	April	End of May
Prepare water chemistry bottles and filters	April	Middle of June
Training and orientation	July	N/A - Ongoing
Field work	July - September	N/A
Final Data Entry and QA/QC	September	September
Annual Report and Analysis and Synthesis Reports	October	June of following year

6.2 Facility and Equipment Needs

Facilities necessary for the completion of this protocol include office space with access to computers for the Project Lead, as well as computers for data input from the seasonal Field Crew. Minimal laboratory facilities are necessary for the steps of acid washing bottles and filter prep, all available through Southern Oregon University Chemistry Department. Seasonal housing for the field crews is also necessary, along with access to refrigeration/freezer usage for storing water samples.

A large amount of equipment is necessary for the completion of this protocol. A complete equipment list is provided in Appendix L, along with quantity needed per site and per sampling season.

6.3 Budget Considerations

Total annual operating budget of the protocol is budgeted for $80,000. This budgetary figure does not include the costs of the core network staff (see below). The annual cost is split between WRD budgetary funds and Klamath Network funding. The first year of implementation budget and protocol has been developed to be under this amount so that inflationary cost increases over the long-term will not jeopardize program viability. Our goal has been to ensure that the program stays financially sound for a minimum of 7 years, under an assumption of no programmatic budget increases. We have assumed a typical inflationary increase in all costs (salary, benefits, sample processing, and equipment) of 3% per year. Hence, to come just under the budget of $80,000, our budget for 2010 (the first year of implementation) is $64,865.50 (Table 15).

Additional budget considerations and costs come from the core network staff, consisting of:

- Project Lead (assuming GS-11 level): approximately 20 pay periods at $2,600 per = $52,000 (the Project Lead time in a lakes year will also include preparation work for stream monitoring in upcoming year)
- Network Coordinator (assuming GS-12 level): approximately 1 pay period at $3,200 per = $3,200.
- Network Administrative Assistant (assuming GS-07 level): approximately 1.5 pay periods at $1,406 per = $2,107.
- Network Data Manager (assuming GS-11 level): approximately 1.5 pay periods at $2,600 per = $3,900.
- Total costs of core network staff = $61,207.

Table 16. Budget for implementation of the Integrated Aquatic Community and Water Quality of Mountain Ponds and Lakes in the Klamath Network Protocol. Numbers in parentheses and red indicate a programmatic deficit, assuming no budgetary increases.

		2010	2013	2016	2019	2022
		Year 0	Year 3	Year 6	Year 9	Year 12
Program Item (@ 2009 costs)						
Salary						
	GS-7 Field Crew Leader 1 FTE @ 8PP; $1460.80 per PP	$ 11,686.40	$ 12,770.04	$ 13,954.17	$ 15,248.10	$ 16,662.01
	GS-5 Crew Member 1 FTE @ 7PP; $1179.20 per PP	$ 8,254.40	$ 9,019.81	$ 9,856.19	$ 10,770.12	$ 11,768.80
Vehicle						
	Field transport/fuel	$ 3,000.00	$ 3,278.18	$ 3,582.16	$ 3,914.32	$ 4,277.28
Travel						
	Lodging and per diem	$ 2,000.00	$ 2,185.45	$ 2,388.10	$ 2,609.55	$ 2,851.52
Equipment						
	Consumables, GPS units, Calibration solutions, etc.	$ 5,000.00	$ 5,463.64	$ 5,970.26	$ 6,523.87	$ 7,128.80
Specimen Processing						
	Zooplankton; 42 samples @ $87.5	$ 3,675.00	$ 4,015.77	$ 4,388.14	$ 4,795.04	$ 5,239.67
	Macroinvertebrates; 42 samples @ $235	$ 9,870.00	$ 10,785.22	$ 11,785.30	$ 12,878.11	$ 14,072.26
	Chlorophyll *a*; 84 samples @ $35	$ 2,940.00	$ 3,212.62	$ 3,510.51	$ 3,836.03	$ 4,191.74
	Water chemistry; 84 samples @$160	$ 13,440.00	$ 14,686.25	$ 16,048.06	$ 17,536.15	$ 19,162.23
QAPP						
	10% extra samples; verification; probe maintenance; etc.	$ 5,000.00	$ 5,463.64	$ 5,970.26	$ 6,523.87	$ 7,128.80
	Total	$ 64,865.80	$ 70,880.61	$ 77,453.16	$ 84,635.16	$ 92,483.12
	Surplus/Deficit	$ 15,134.20	$ 9,119.39	$ 2,546.84	$ (4,635.16)	$ (12,483.12)

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